1. Roy Eason

E82-10056

FC-L0-00480 CR-161024
7. JSC-16380
NOV 10 1980

AgRISTARS

A Joint Program for Agriculture and Resources Inventory Surveys Through Aerospace Remote Sensing

Foreign Commodity Production Forecasting

6. October 1980
5. NAS9-15800

CORN/SOYBEAN DECISION LOGIC DEVELOPMENT AND TESTING

NASA CR-161024

3. C. L. Dailey and K. M. Abotteen

(E82-10056) AGRISTARS: FOREIGN COMMODITY PRODUCTION FORECASTING. CORN/SOYBEAN DECISION LOGIC DEVELOPMENT AND TESTING (Lockheed Engineering and Management) 81 p HC A05/MF A01 CSCL 02C G3/43
N82-19631
Unclas 00056

4. LOCKHEED ENGINEERING AND MANAGEMENT SERVICES COMPANY, INC.
1830 NASA Road 1, Houston, Texas 77058

Lyndon B. Johnson Space Center
Houston, Texas 77058

FC-LO-00480
JSC-16380

TECHNICAL REPORT

CORN/SOYBEAN DECISION LOGIC DEVELOPMENT AND TESTING

Job Order 73-315

This report describes labeling logic development activities performed by the classification element of the Foreign Commodity Production Forecasting project of the AgRISTARS program.

PREPARED BY

C. L. Dailey and K. M. Abotteen

APPROVED BY

R. W. Payne
for L. M. Flores, Supervisor
Design Integration Section

B L Carroll
B. L. Carroll, Manager
Commodity Forecasting Department

LOCKHEED ENGINEERING AND MANAGEMENT SERVICES COMPANY, INC.
Under Contract NAS 9-15800

For

Earth Observations Division
Space and Life Sciences Directorate
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
LYNDON B. JOHNSON SPACE CENTER
HOUSTON, TEXAS

October 1980

LEMSCO-14811

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
JSC-16380; FC-LO-00480		
4. Title and Subtitle Corn/Soybean Decision Logic Development and Testing		5. Report Date October 1980
		6. Performing Organization Code
7. Author(s) C. L. Dailey and K. M. Abotteen Lockheed Engineering and Management Services Company, Inc.		8. Performing Organization Report No. LEMSCO-14811
		10. Work Unit No.
9. Performing Organization Name and Address Lockheed Engineering and Management Services Company, Inc. 1830 NASA Road 1 Houston, Texas 77058		11. Contract or Grant No. NAS 9-15800
		13. Type of Report and Period Covered Technical Report
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Lyndon B. Johnson Space Center Houston, Texas 77058 Technical Monitor: R. O. Hill		14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract

This paper shows the development and testing of an analysis procedure which was developed to improve the consistency and objectivity of crop identification using Landsat data. The procedure was developed to identify corn and soybean crops in the U.S. Corn Belt region. The procedure consists of a series of decision points arranged in a tree-like structure, the branches of which lead an analyst to crop labels. The specific decision logic is designed to maximize the objectivity of the identification process and to promote the possibility of future automation. In this report, development and testing of the procedure are outlined and a summary of significant results is presented.

17. Key Words (Suggested by Author(s))	18. Distribution Statement
Corn, crop identification, decision logic, hierarchy, labeling logic development, labeling procedures, soybeans	

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price*
Unclassified	Unclassified	82	

PRECEDING PAGE BLANK NOT FILMED

PREFACE

This report offers a detailed description of the decision logic and procedure developed for identification of corn and soybeans in the U.S. Corn Belt. Development and testing of the procedure are outlined and a summary of significant results is presented.

The development and testing of the corn/soybean decision logic procedure was a team effort which required the expertise of many individuals. The major effort of designing the hierarchical structure of the decision logic was coordinated by W. P. Palmer, who documented the initial decision logic in an internal communication (section 5). Major sections of that document are reproduced in this report. J. D. Nichols and W. L. West analyzed image and ground-truth data and constructed the cropland identification step of the decision logic. T. E. Johnson, B. B. Schroder, and R. D. Pickerel developed the initial framework for the separation of corn and soybeans using image products of the Large Area Crop Inventory Experiment. W. W. Austin aided in the analysis of spectral aids. These individuals were major contributors to the development of the corn/soybean decision logic.

The authors would like to thank the analysts from both the National Aeronautics and Space Administration and Lockheed Engineering and Management Services Company, Inc. who participated in the tests. Also, the authors wish to thank J. G. Carnes for the preliminary test results which appear in this paper.

CONTENTS

Section | Page

TABLES

PRECEDING PAGE BLANK NOT FILMED

FIGURES

1. INTRODUCTION

This paper shows the development and testing of an analysis procedure which was developed to improve the consistency and objectivity of crop identification using Landsat data. The procedure was developed to identify corn and soybean crops in the U.S. Corn Belt region. The procedure consists of a series of decision points arranged in a tree-like structure, the branches of which lead an analyst to crop labels. The specific decision logic is designed to maximize the objectivity of the identification process and to promote the possibility of future automation.

In prior procedures, the interpretation function was more loosely structured and many steps were very subjective. The analyst was responsible for accumulating information from various sources, assimulating and integrating the information in order to determine the most likely label for a signature. Labeling accuracies of these procedures were related to the experience of the analyst, and labeling errors were sometimes hard to diagnose.

This decision logic is a hierarchy of decisions that uses a step-by-step procedure to lead the analyst from general major land-use categories to the specific identification of corn and soybean signatures. In the first step, analysis of the signatures on the imagery is governed by answers given at decision points on the decision tree and results in the differentiation of cropland from other major land-use categories. In step two, image products are used to answer more specific questions to separate cropland into summer and nonsummer crops. In step three, summer crops are identified as definite corn and soybeans through the aid of numerical spectral information in graphic form. Any remaining signatures are labeled in step four by comparing them to definite corn and soybean profiles and choosing the label of the most similar profile. Each component of the decision logic will be further discussed in terms of its function, strengths, and weaknesses.

Two tests were performed to evaluate the decision logic. Labeling accuracies pertaining to the developmental task are summarized, and procedural problems and recommendations are discussed in this paper. The complete analysis of the accuracy of the tests is contained in an accuracy assessment report (ref. 1).

2. OBJECTIVES

This research effort was designed to develop and test a decision logic for corn and soybean identification. The objectives of the effort were to

- Define a tree-type structure of decision points that describes the image interpretation process
- Determine from all available analyst aids those to be used at various decision points
- Define a procedure so that labeling errors can be easily diagnosed
- Test the decision logic and obtain labeling results for further development

3. DATA SET

Eight segments (9- by 11-kilometer area), located in four agrophysical units (APU) of the U.S. Corn Belt, were used in developing the technique. Table 3-1 displays the segment numbers, locations, APU's, available acquisitions, and major crops. The data set is selected according to the following criteria:

a. Presence of the crops of interest (corn and soybeans)

b. Good acquisition histories

c. Availability of ground-truth data

The products available for analyst use include: (1) Landsat film products which are false color composites of three bands out of the four bands of the satellite's multispectral scanner (MSS), (2) crop calendars, (3) meteorological summaries, and (4) spectral aids in the form of plots of transformed spectral values from the MSS.

There are three types of film products: Product 1 is a simulated color-infrared (CIR) composite image using Landsat bands 4, 5, and 7 of the Landsat MSS (ref. 2); Product 2 is an enhanced image using Landsat bands 5, 6, and 7; and Product 3 is a simulated CIR composite image using Landsat bands 4, 5, and 7 with different gains and biases set to minimize color distortion. Each product is 196 pixels (picture elements) across and 117 lines down and is partitioned by a 10-by-10 grid system.

Two types of crop calendars were used. Normal crop calendars were generated for corn and soybeans within designated crop reporting districts (CRD's) in the corn belt. The calendars, as shown in figure 3-1, display the percentage (Y-axis) of a crop that is at or past a specific growth stage. The time (X-axis) is displayed in 15-day intervals throughout the growing season. These calendars are based on two or more years of historical data. Current-year crop calendars were constructed from actual field observations collected on approximately 10 fields per segment at various points throughout the growing season. The format of the current-year crop calendar is shown in figure 3-2.

TABLE 3-1.- THE DEVELOPMENT DATA SET

Segment	Location	APU	Acquisition date (Julian data)	Major crops
209	Gentry, Missouri	25	June 16 (167) July 4 (185) July 31 (212) Aug 8 (220) Aug 9 (221) Sept 4 (247) Sept 22 (265) Sept 23 (266) Oct 1 (274) Oct 19 (292)	Corn Soybeans Hay Pasture
211	Grundy, Missouri	25	June 15 (166) July 3 (184) July 21 (202) Aug 8 (220) Sept 4 (247) Sept 22 (265) Oct 1 (274) Oct 19 (292) Oct 28 (301)	Corn Soybeans Sorghum Hay Pasture
804	Marshall, Iowa	24	June 15 (166) Aug 17 (229) Sept 4 (247) Sept 22 (265) Oct 1 (274) Oct 19 (292)	Corn Soybeans Oats Pasture
824	Iroquois, Illinois	28	June 12 (163) Aug 5 (217) Aug 23 (235) Aug 31 (243) Sept 1 (244) Sept 9 (252) Sept 28 (271) Nov 2 (306) Nov 3 (307)	Corn Soybeans Oats Hay

TABLE 3-1.- Concluded.

Segment	Location	APU	Acquisition date (Julian data)	Major crops
854	Tippecanoe, Indiana	28	June 10 (161) July 26 (207) Aug 9 (221) Aug 21 (233) Aug 22 (234) Sept 8 (251) Sept 9 (252) Sept 26 (269) Sept 27 (270) Nov 2 (306) Dec 17 (351)	Corn Soybeans Clover Pasture
883	Palo Alto, Iowa	24	July 5 (186) July 23 (204) Aug 1 (213) Aug 10 (222) Sept 24 (267) Oct 20 (293) Oct 30 (303)	Corn Soybeans Hay Pasture
886	Pottawatomie, Iowa	14	June 16 (167) July 5 (186) July 23 (204) July 31 (212) Sept 6 (249) Sept 15 (258) Sept 24 (267) Oct 20 (293) Nov 7 (311)	Corn Soybeans Oats Pasture
892	Shelby, Iowa	14	June 16 (167) July 23 (204) Aug 9 (221) Sept 23 (266) Sept 24 (267) Oct 20 (293)	Corn Soybeans Oats Hay Pasture

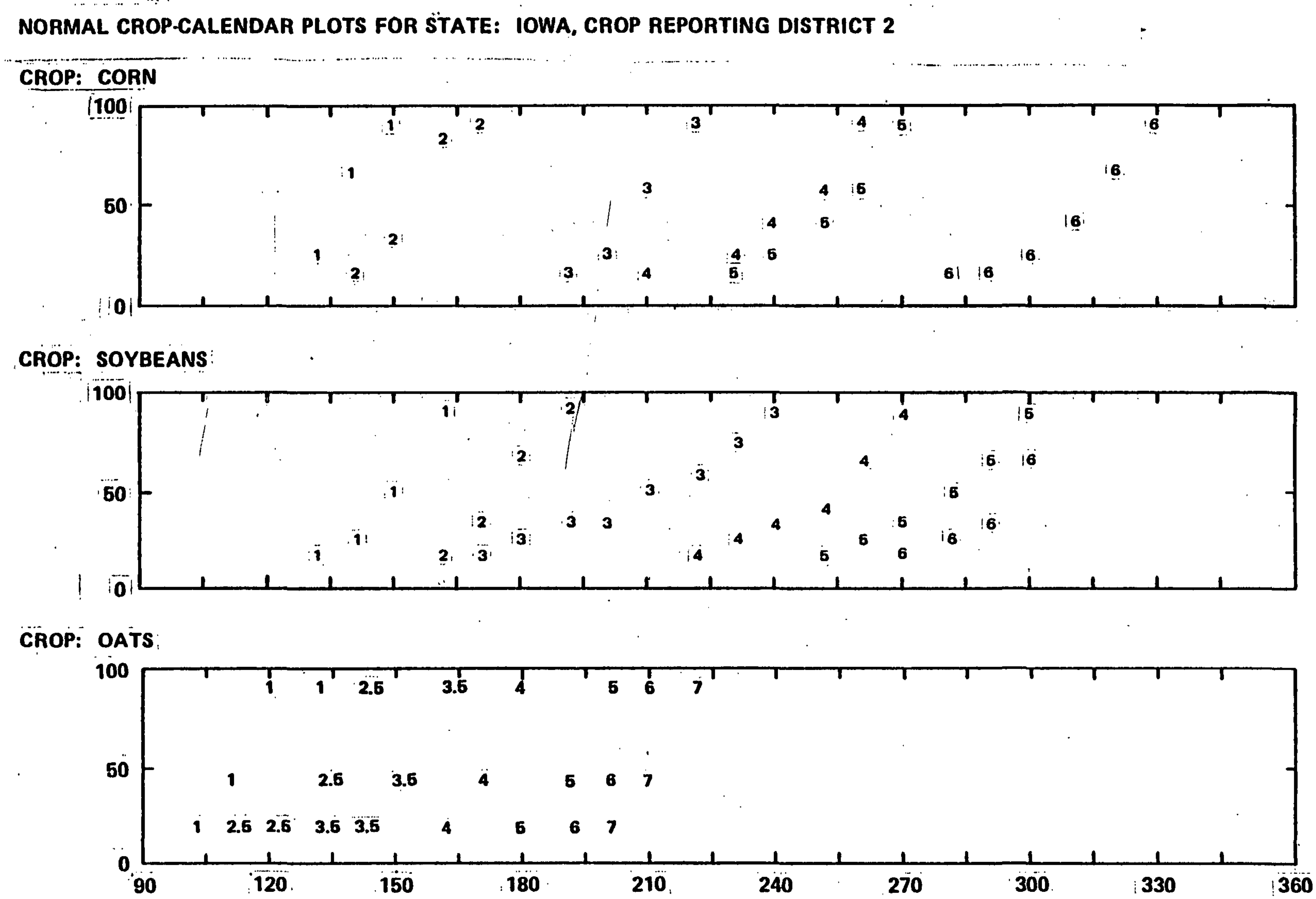


Figure 3-1.- Normal crop calendar.

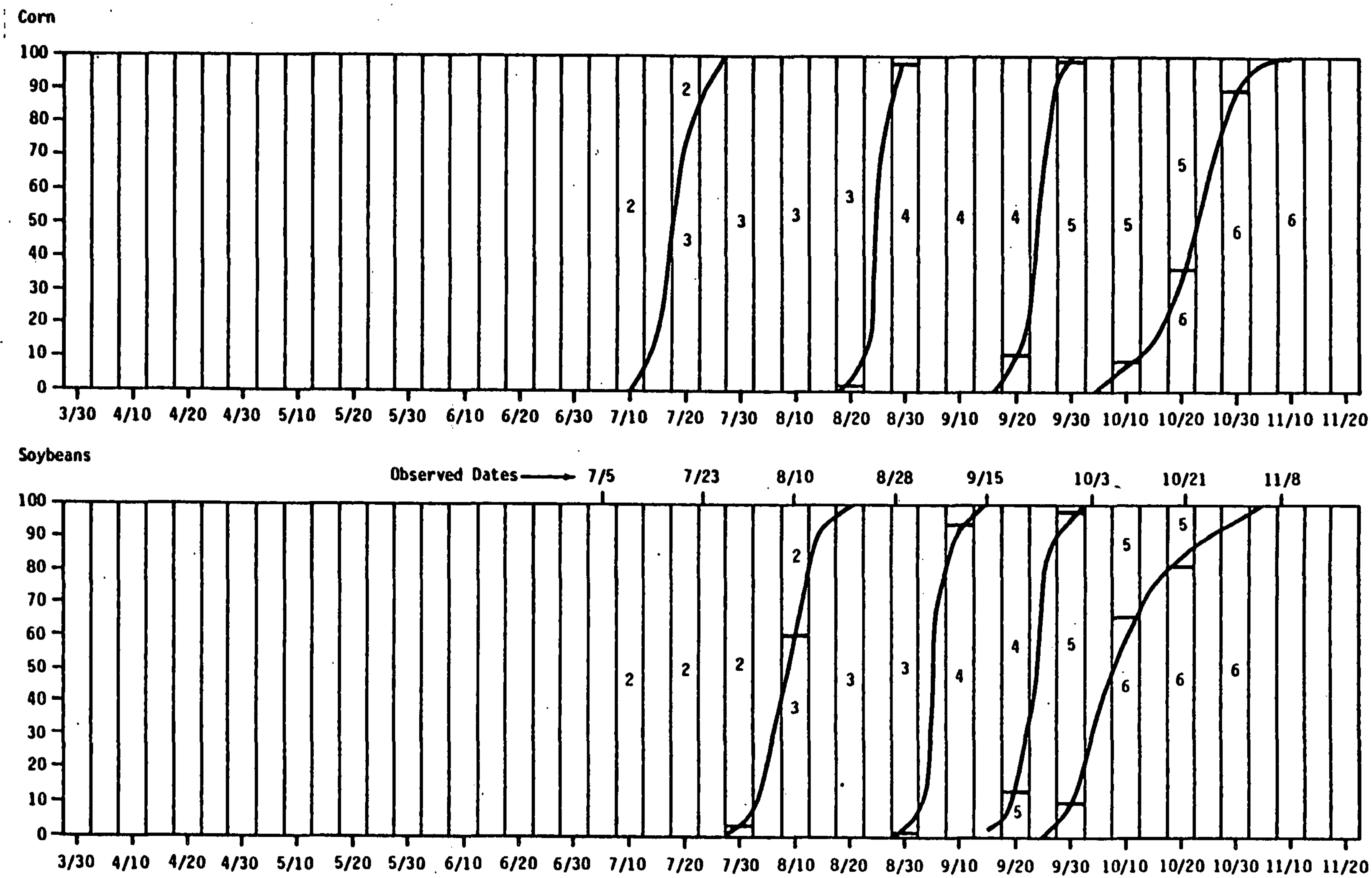


Figure 3-2.- Current year crop calendar for segment 883.

The meteorological summaries offer a synopsis of the weather at the state level and are available on a weekly basis.

Spectral aids which include scatter plots, time plots, and trajectory plots are generated before interpretation to aid in labeling. The data (209 grid intersection pixels called dots) are transformed into Kauth space before the aids are generated (ref. 3) and greenness is changed to green number by subtracting a calculated soil line (ref. 4).

The scatter plot in figure 3-3 is a graphic representation of the transformed MSS data. The typical green-number-versus-brightness scatter plot is triangular in shape. The base of the triangle contains the bare soil pixels. The distance of a pixel from the base is a measure of vegetation canopy and the distance that a pixel is from the Y-axis is a measure of its brightness. A scatter plot is generated for each acquisition in the data base.

Time plots display green number versus time and brightness versus time, as shown in figure 3-4. Two dots (pixels) are plotted per graph for every usable acquisition in the data base. Time plots show the changes in green number and/or brightness for a particular pixel over an entire growing season.

A trajectory plot displays a spectral pattern for a pixel over a period of time. It uses the same axes information as does a scatter plot, but it contains data on one pixel for up to eight acquisitions, as shown in figure 3-5.

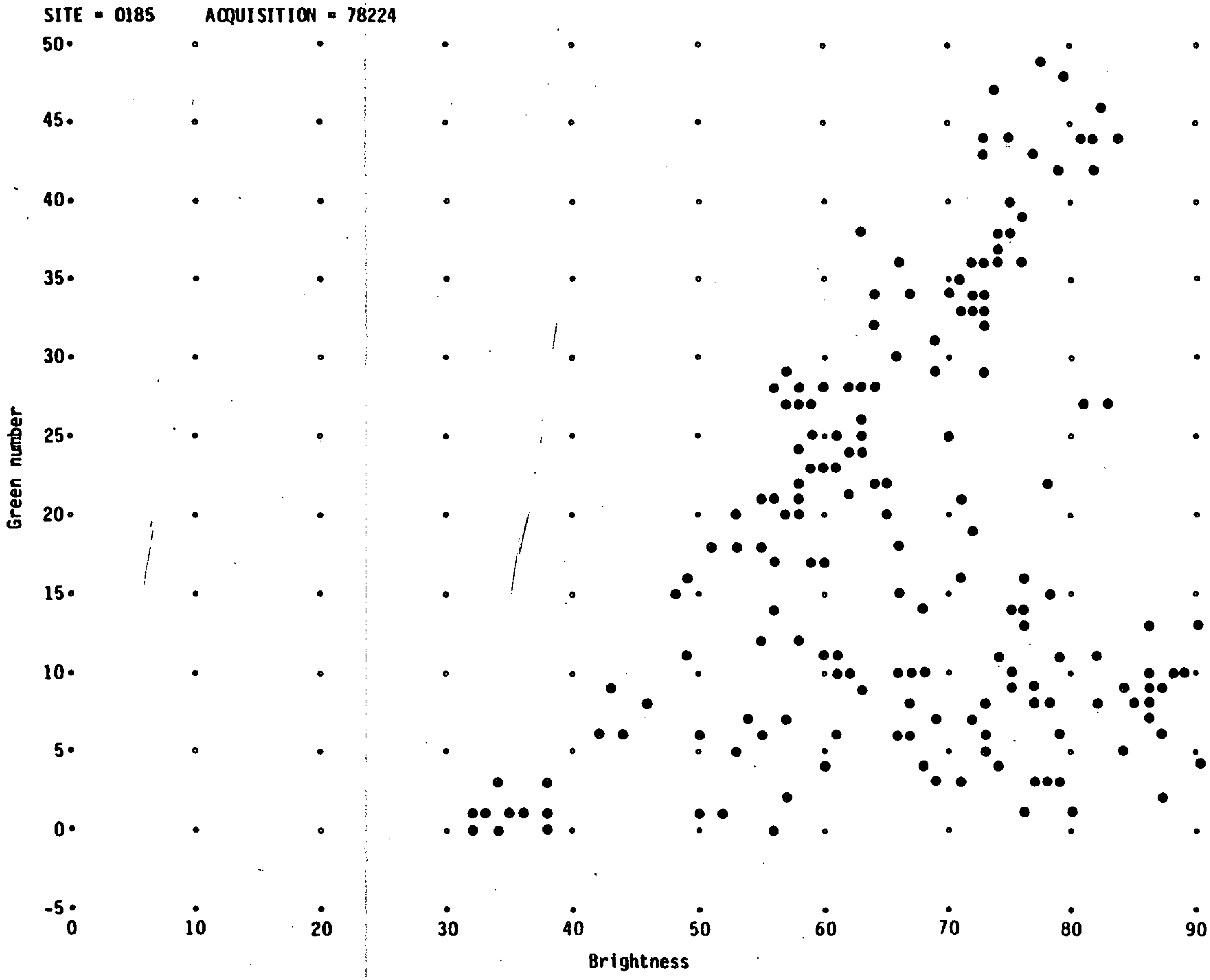


Figure 3-3.- Scatter plot.

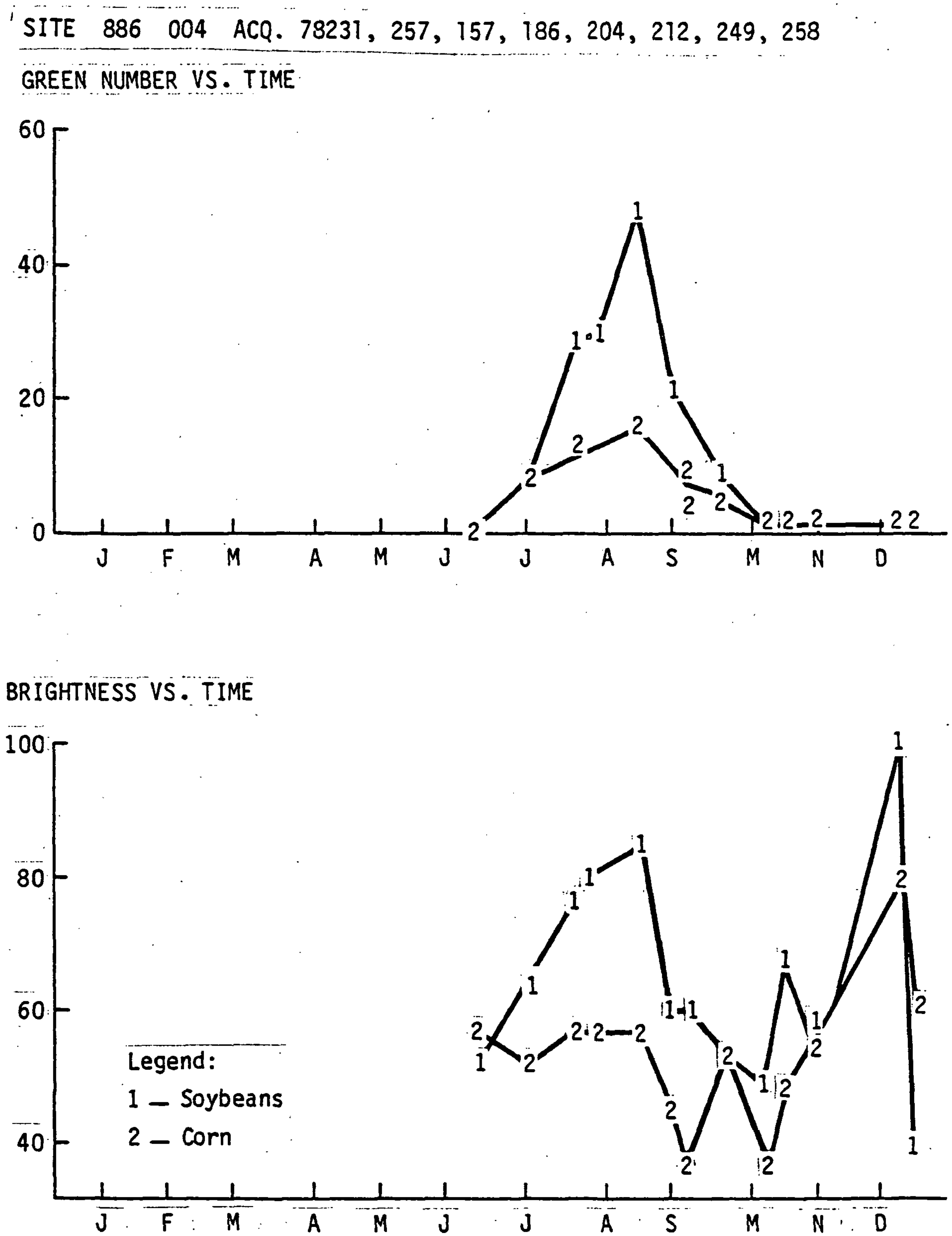
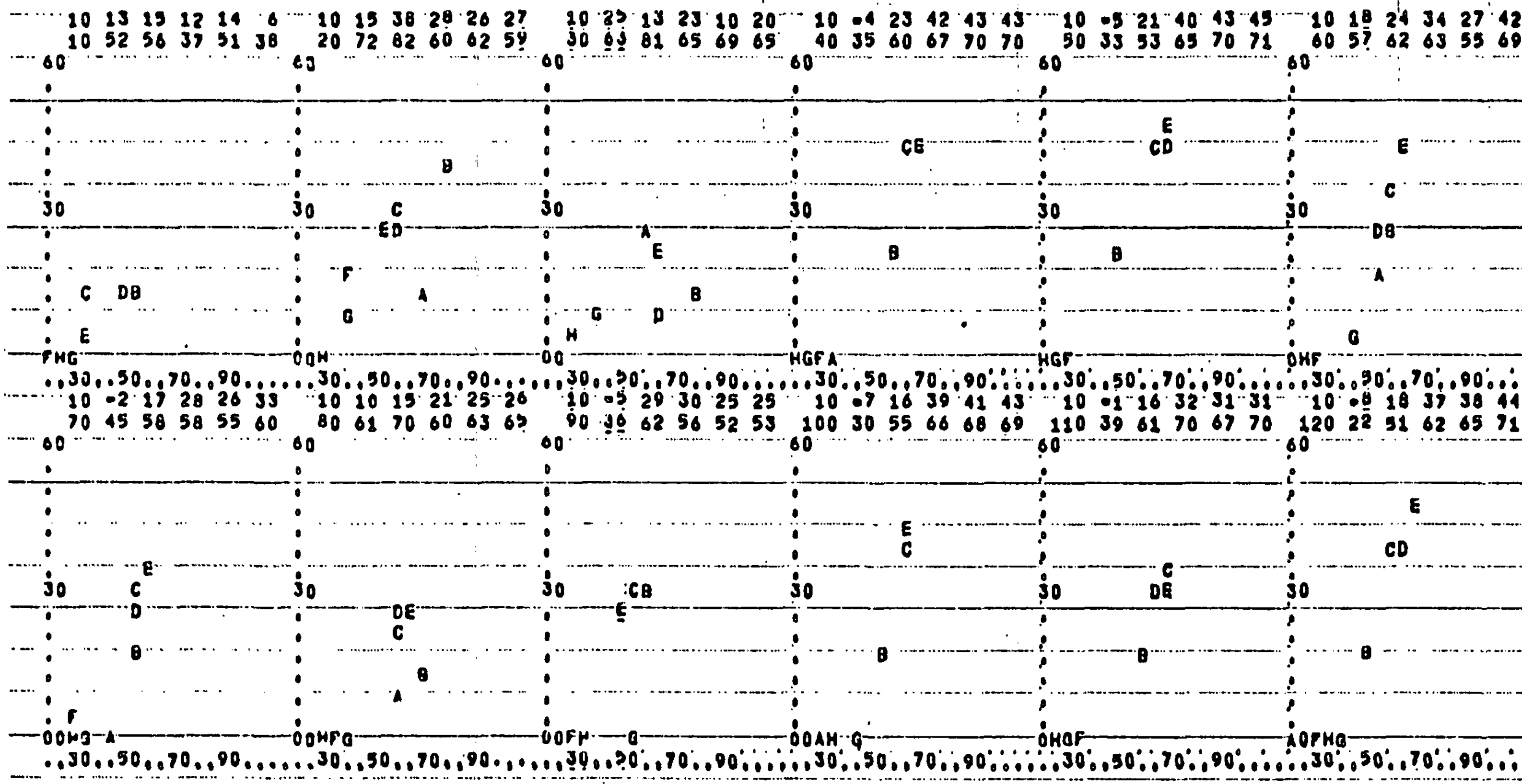


Figure 3-4.- Time plots for labeling dots.

ORIGINAL PAGE IS
OF POOR QUALITY



SEGMENT	ACQ.	SYMBOL	SEGMENT	ACQ.	SYMBOL
883	78150	A	883	78222	E
883	78186	B	883	78267	F
883	78204	C	883	78293	G
883	78213	D	883	78303	H

Figure 3-5.-Trajectory plots. The grid intersection and green number and brightness values for the first five acquisitions are printed at the top of each plot. Due to the scale of the plot, values may fall in the same position on the plot and not be represented with a letter.

4. TECHNICAL APPROACH

The approach to the task (ref. 5) consisted of two phases. In the first phase, the then current procedures for labeling small grains (ref. 6) were examined for their applicability to the corn/soybeans case. Typically, these procedures consist in the examination of various alternative pieces of evidence to make a decision relating to land usage. Thus, the first step was to make this decision process more objective by eliminating the alternatives. Only one of the alternatives was selected for the decision. Then, the process was formalized by reformatting it in the form of decision points arranged in a tree-like structure. In the second phase, a separate effort was mounted to address the decision-making for the decisions that were more specifically related to corn and soybeans. These decisions were also formatted in a tree-structured approach.

In order to design the structure of each step of the second phase of the study, the different land uses and crop types were observed on each of the analyst aids to identify distinctive characteristics and trends. Ground-truth information was used when analyzing the film products and the spectral aids. Ground-truth labels were obtained from an annotated aerial photograph with a registered grid overlay. The grid overlay corresponds to the film product grid. The ground-truth pixels which were used for this study spectrally and spatially represent only one category (pure pixel).

Acquisition-specific information was collected and analyzed for corn and soybeans. Appendix A contains an explanation and table of that information. These data were then used to define biowindows and image characteristics of the corn and soybeans. The spectral aids were examined for patterns which would separate corn and soybeans from each other and from other crop types (ref. 7). Then each of the analyst aids were evaluated according to their suitability for use at specific decision points. Thus, a structure was built up using these objective observations to make decisions, each of which would be an element of the structure, and each branch or set of decisions would lead the analyst to a crop identification and label.

Two tests were performed using the corn/soybean decision logic. The first experiment was designed to identify problems with the procedure and provide for improvements before further testing. Labeling accuracies and the effects of the group (analyst) and region were addressed. The second test was designed to perform a within-strata variance study and estimate sampling and classification variance. This information would then be an input to a simulated aggregation. This test allowed for the use of the labeling logic in an operational-type environment. Only preliminary labeling results have been obtained on this second test.

5. DESCRIPTION OF THE DECISION LOGIC

The procedure developed from the analysis of the analyst aids available for the eight segments uses Landsat data in both imagery format and spectral aids as input. The logic diagram that leads to land usage and crop identification consists of four steps:

Step 1 — identification of cropland

Step 2 — identification of summer cropland

Step 3 — identification of definite corn and soybean signatures

Step 4 — identification of the remaining signatures

5.1 STEP 1 — IDENTIFICATION OF CROPLAND

Step 1 consists of the series of decision points arranged in the tree-like structure (decision tree) presented in figure 5-1. All workable simulated CIR Landsat acquisitions over the segment are used to sort the signatures in the scene into land-use categories. A minimum data set of two acquisitions is necessary for use of this tree. However, the decision tree is normally used in conjunction with the subsequent steps which impose more stringent requirements on the data set. The lowest level crop(s) of interest dictate the minimum data set.

To identify the land use associated with a particular signature, the analyst follows a path determined by the decisions given at the decision points encountered. The questions asked at each decision point are keyed by number, as shown in figure 5-1, and appear in figure 5-2. Each decision point is designed to use information extracted from the imagery based on the color of the crop in an acquisition in relation to the color in other acquisitions. The pathway thus defined allows for the identification of major land-use categories. Definitions and characteristics of categories identified in this step can be found in appendix B. Since definitions from other sources (ref. 8) combine categories that are separable with this procedure or alternatively include features which are too small to be detected on Landsat

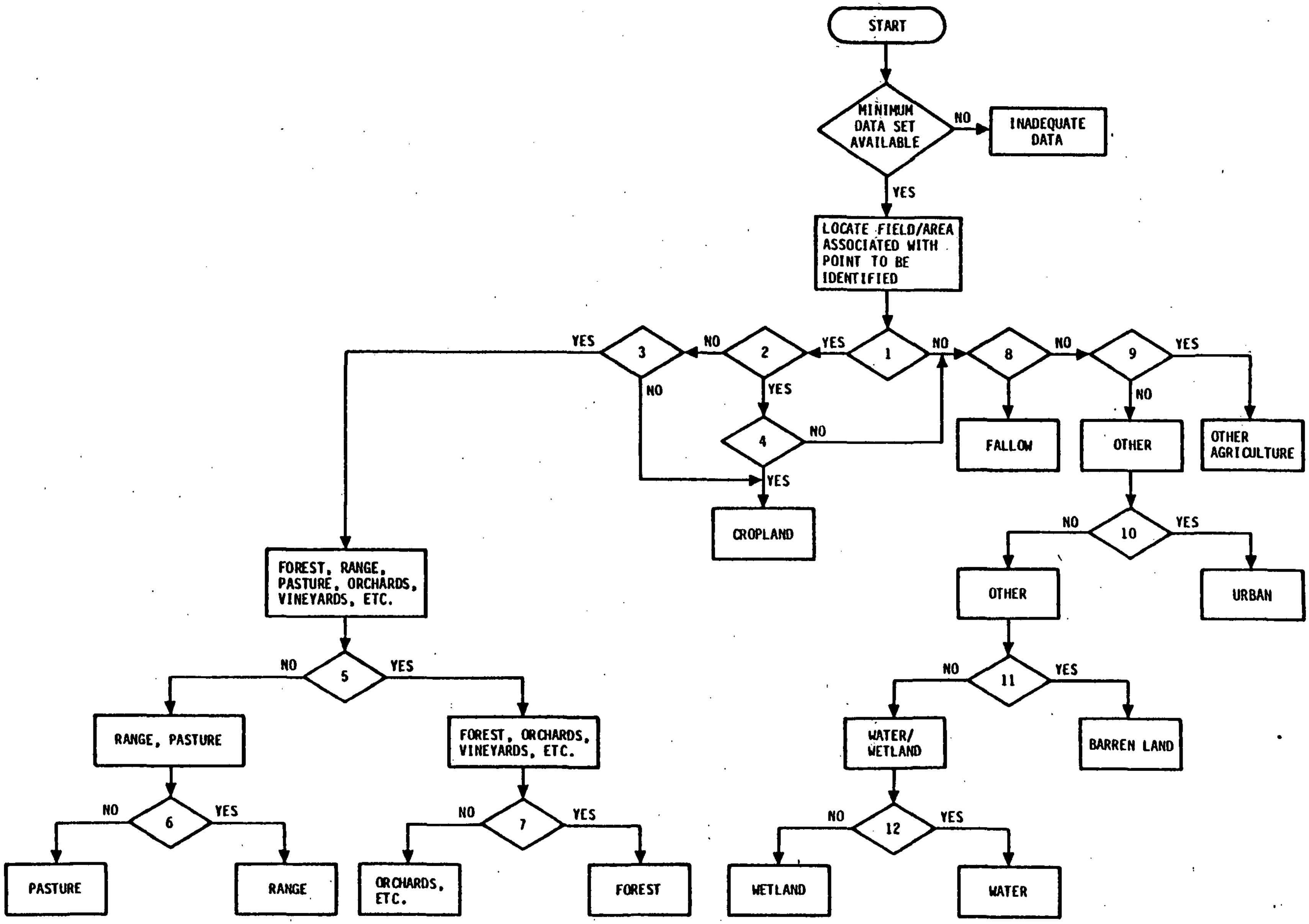


Figure 5-1.- Diagram of decision tree for major land-use categories (Step 1).

DECISION CRITERIA FOR MAJOR LAND-USE CATEGORIES

1. Is the area some shade of red (red, pink, brown, orange, etc.) on at least one acquisition?

2. Does the area appear to be water (dark blue-black to bright blue) on any of the acquisitions?

3. Is the area some shade of red on all acquisitions (i.e., no planting or harvest appearance)?

4. Is the area harvested (blue, green, white, gray, yellow) on an acquisition following the one in which it appeared red?

5. Is the area red or reddish brown throughout the year, with the color most intense during the late spring or early summer? (Some trees lose their leaves annually and may appear dark brown during the winter.)

6. Is the area large and irregular?

7. Is the area large relative to the economic endeavor of the area, along a drainage network, and bright red in late spring and early summer and reddish brown or brown at other times?

8. Is the shape of the area similar to areas that have been identified as cropland and the color green or blue (may vary from dark to light during the year) on all acquisitions?

9. Is the area small and white to dull gray?

10. Is the area irregular in shape and a constant white to mottled steel blue throughout the year?

11. Does the area appear to be constantly bright with no green vegetation and no seasonal change in shape or size?

12. Does the area appear dark blue-black to bright blue on all acquisitions? (Size and shape may change during year, but area is not seasonally wet.)

Figure 5-2.- Decision criteria questions keyed to the decision points in figure 5-1.

imagery, definition of the categories as used in the decision tree are necessary. All major land-use categories are labeled except for cropland which will be refined through further analysis. Labels are always associated with the dot which represents the area and signature being identified.

5.2 STEP 2 — IDENTIFICATION OF SUMMER CROPLAND

The signatures identified as cropland in Step 1 are separated into summer and nonsummer cropland by following Step 2. In order to perform this step, three biowindows are defined using the corn and soybean historical crop calendars, the 18-day ground truth observations, and Landsat CIR film products. (The ground truth observations are used only for development; ground truth information is not available during testing.) A biowindow is a time in the growth cycle of a crop when predictable Landsat signatures can be identified. Corn and soybean biowindows are described in table 5-1, and crop growth stage numbers for corn and soybeans are shown in table 5-2.

Figure 5-3 is a display of the crop calendar annotated with the defined biowindows. Figure 5-4 is the flow diagram for separating summer and nonsummer cropland. Fields that are bare soil (not red on imagery) on at least one acquisition in biowindow A, green vegetation (red on imagery) on all acquisitions in biowindow B, and ripe and/or harvested (not red on imagery) on all acquisitions in biowindow C are identified as summer crops. The nonsummer crop signatures are labeled at this point and the summer crop signatures are further processed in Step 3.

Dots which represent more than one signature either as a boundary between two categories or because of misregistration between acquisitions are identified and appropriately documented during this step because this is usually the last step that requires film products. Misregistered dots may be reserved for labeling in Step 4.

TABLE 5-1.- CORN AND SOYBEAN BIOWINDOWS

Bio-window	Definition[a]		Description of expected Characteristics
	Open on latest	Close on earliest	
A	C 30%>1 S 30%>1	C 80%>2 S 10%>2	Plowing, planting, pre-emergence, or very early emergence for summer crops
B	C 50%>3 S 10%>3	C 30%>5 S 10%>5	Full ground cover and green vegetation for summer crops
C	C 100%>5 S 100%>5	C 80%>6 +30 days S 80%>6 +30 days	Mature, harvest, and post-harvest for summer crops

[a]For example, entry C 30%>5 means that, according to the normal crop calendar, corn is 30 percent past stage 5 (maturity). Dates should be determined for both corn and soybeans and the latest used to open windows, the earliest to close windows.

TABLE 5-2.- GROWTH STAGE NUMBERS FOR CORN AND SOYBEANS

Growth stage number	Corn growth stage	Soybean growth stage
0	Plowing	Plowing
1	Planting	Planting
2	Floral initiation	Rapid nodal development
3	Tassel-silk	Full pod
4	Denting	Full seed
5	Maturity	Maturity
6	Harvest	Harvest

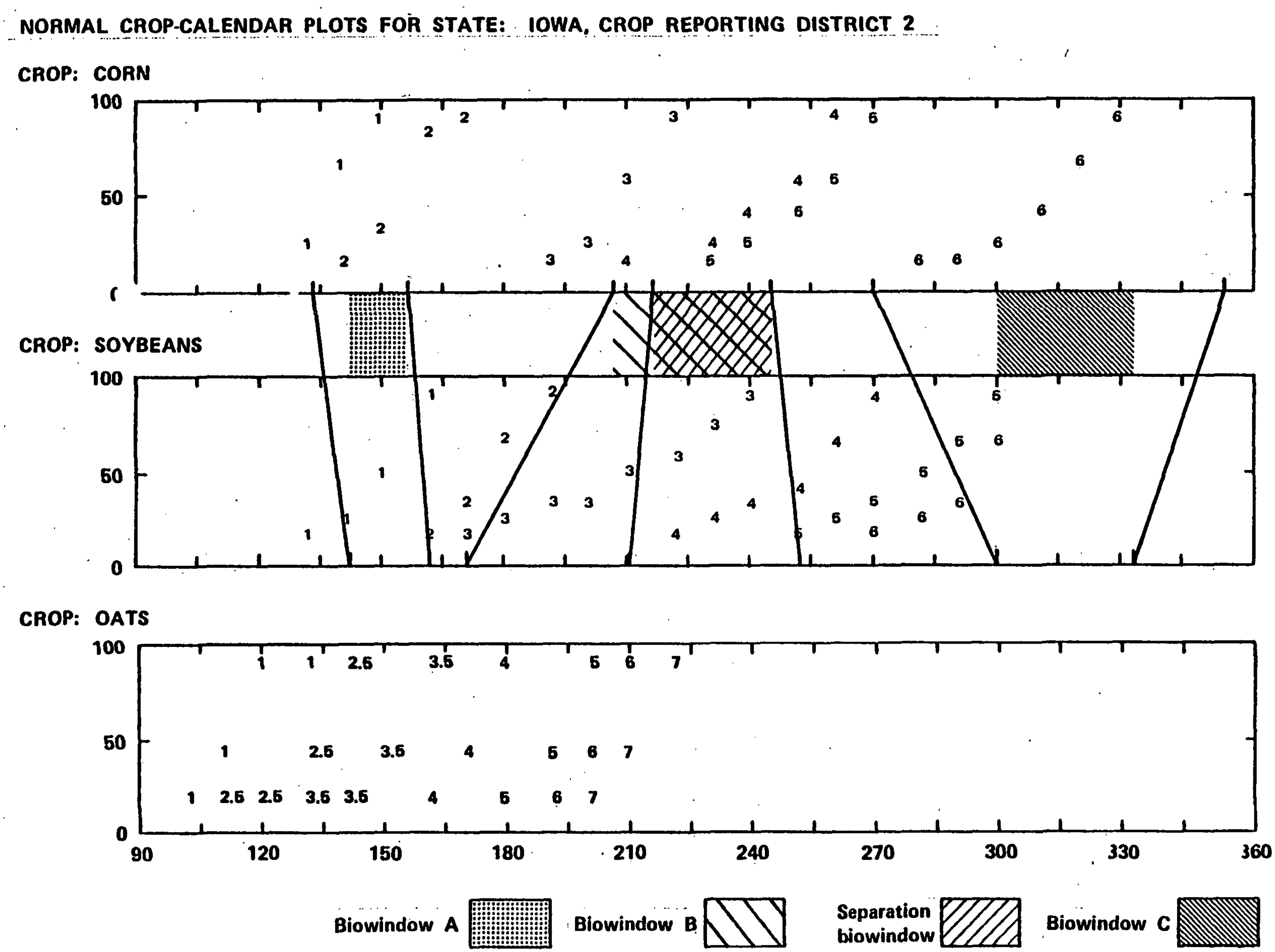


Figure 5-3.- Crop calendar annotated with biowindows.

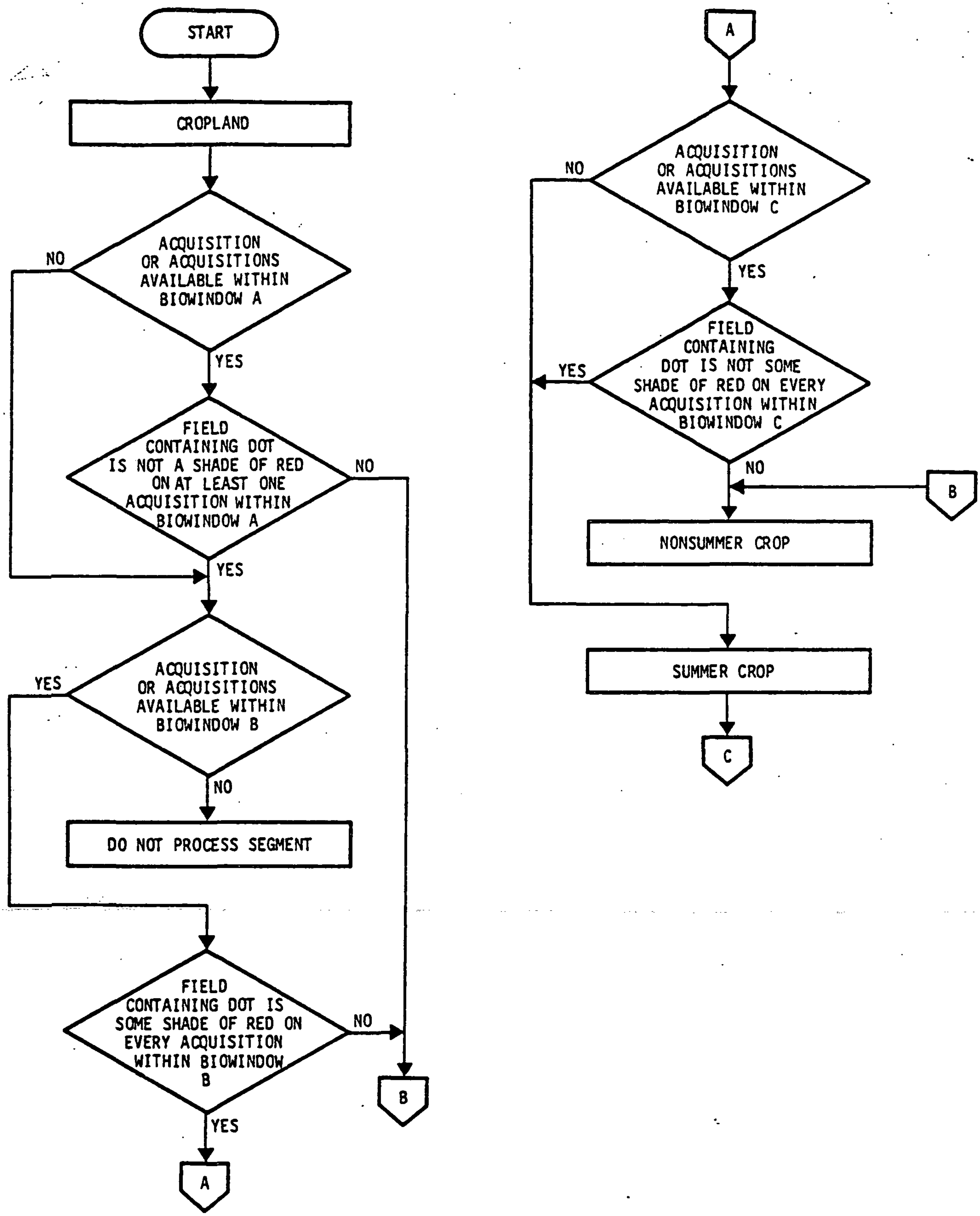


Figure 5-4. - Diagram of decision logic for summer and nonsummer cropland separation (Step 2).

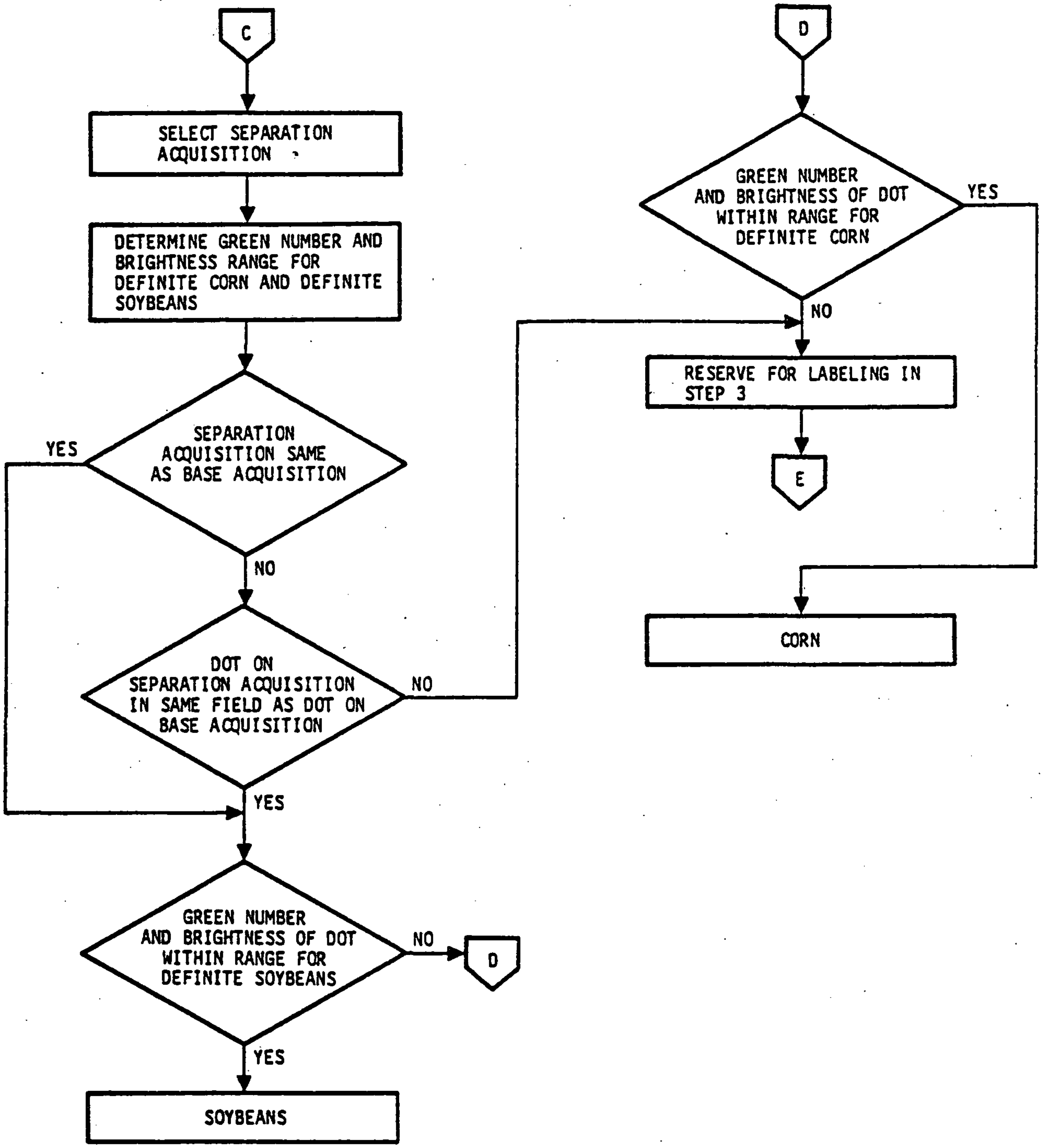


Figure 5-5.- Diagram of decision logic for identifying definite corn and soybeans (Step 3).

5.3 STEP 3 — IDENTIFICATION OF DEFINITE CORN AND SOYBEAN SIGNATURES

The logic flow of this step is diagrammed in figure 5-5. A minimum data set is required for identifying corn and soybeans. Two acquisitions are necessary, one acquisition in either biowindow A or biowindow C and one acquisition in a subset of biowindow B, called a separation biowindow, and defined as shown in the following table.

Definition		Description of expected characteristics
Open on latest	Close on earliest	
C 90%>3 S 50%>3	C 30%>5 S 10%>5	Most of the corn is in the denting stage, and most of the soybeans are in the full pod stage.

A green-number-versus-brightness scatter plot of 209 unlabeled dots selected by systematic random sampling from within the scene is generated for each acquisition in the separation biowindow. An analyst team (3 to 5 analysts) determines which acquisition has the best separation or natural break in the data. Lines are drawn through the break in the data that best separates the two groupings. One of the groupings will be associated with corn and the other with soybeans. The lines are constrained to be parallel to the x and y axes. Then, five counts are added and subtracted from the lines, as shown in figure 5-6. The shaded area accounts for areas of over-lapping categories. All summer crop dots that fall outside the limits in quadrant 1 are labeled soybeans, and all summer crop dots that fall outside the limits in quadrant 3 are labeled corn. Table 5-3, which shows the green number and brightness table generated with the scatter plot, is used to expedite this process. All dots within the limiters (shaded area) are reserved for labeling in Step 4 along with misregistered dots.

5.4 STEP 4 — IDENTIFICATION OF THE REMAINING SIGNATURES

Two methods of analyzing the remaining dots are represented in the flow diagram (figure 5-7) depending on the type of dot being labeled. If the dot is misregistered (edge dot), then the area the dot is in on the base

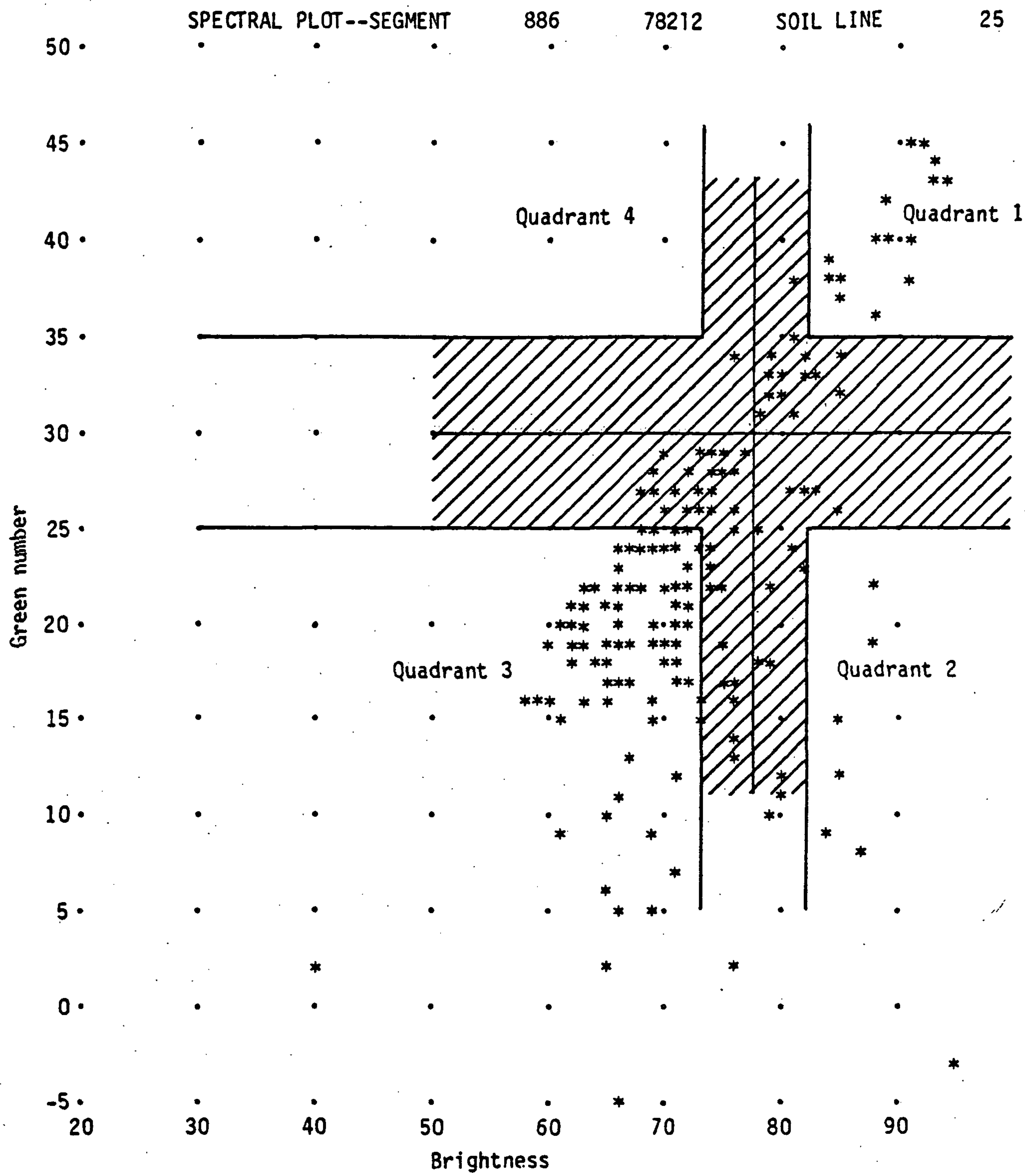


Figure 5-6.- Delineation of break in data and limiters on scatter plot for Step 3.

TABLE 5-3.- SCATTERPLOT TABLE SHOWING EXAMPLES OF STEP 3 AND 4 DOT VALUES

Dot number	Line	Pixel	Label	Green number	Brightness number
1	1	1	**	43	[a]94
2	1	2	**	21	[b]67
3	1	3	**	16	[b]68
4	1	4	**	31	[c]81
5	1	5	**	39	[a]86
6	1	6	**	27	[c]74
7	1	7	**	-7	66
8	1	8	**	32	80
9	1	9	**	23	69
10	1	10	**	2	76
[b]11	[b]1	[b]11	[b]**	27	74
12	1	12	**	36	88
13	1	13	**	14	61
14	1	14	**	16	68
[b]15	[b]1	[b]15	[b]**	23	72
16	1	16	**	16	75
17	1	17	**	27	82
18	1	18	**	19	70
[b]19	[b]1	[b]19	[b]**	24	72
20	2	1	**	15	69
21	2	2	**	43	93
22	2	3	**	18	67
23	2	4	**	-3	95
24	2	5	**	16	76
25	2	6	**	24	69
26	2	7	**	27	67
27	2	8	**	26	74
28	2	9	**	21	61
29	2	10	**	40	89
30	2	11	**	21	72
31	2	12	**	22	67
32	2	13	**	40	91
33	2	14	**	19	66
34	2	15	**	18	70
35	2	16	**	38	86
36	2	17	**	8	87
37	2	18	**	34	85

[a]Soybeans
[b]Corn
[c]Step 4 dot

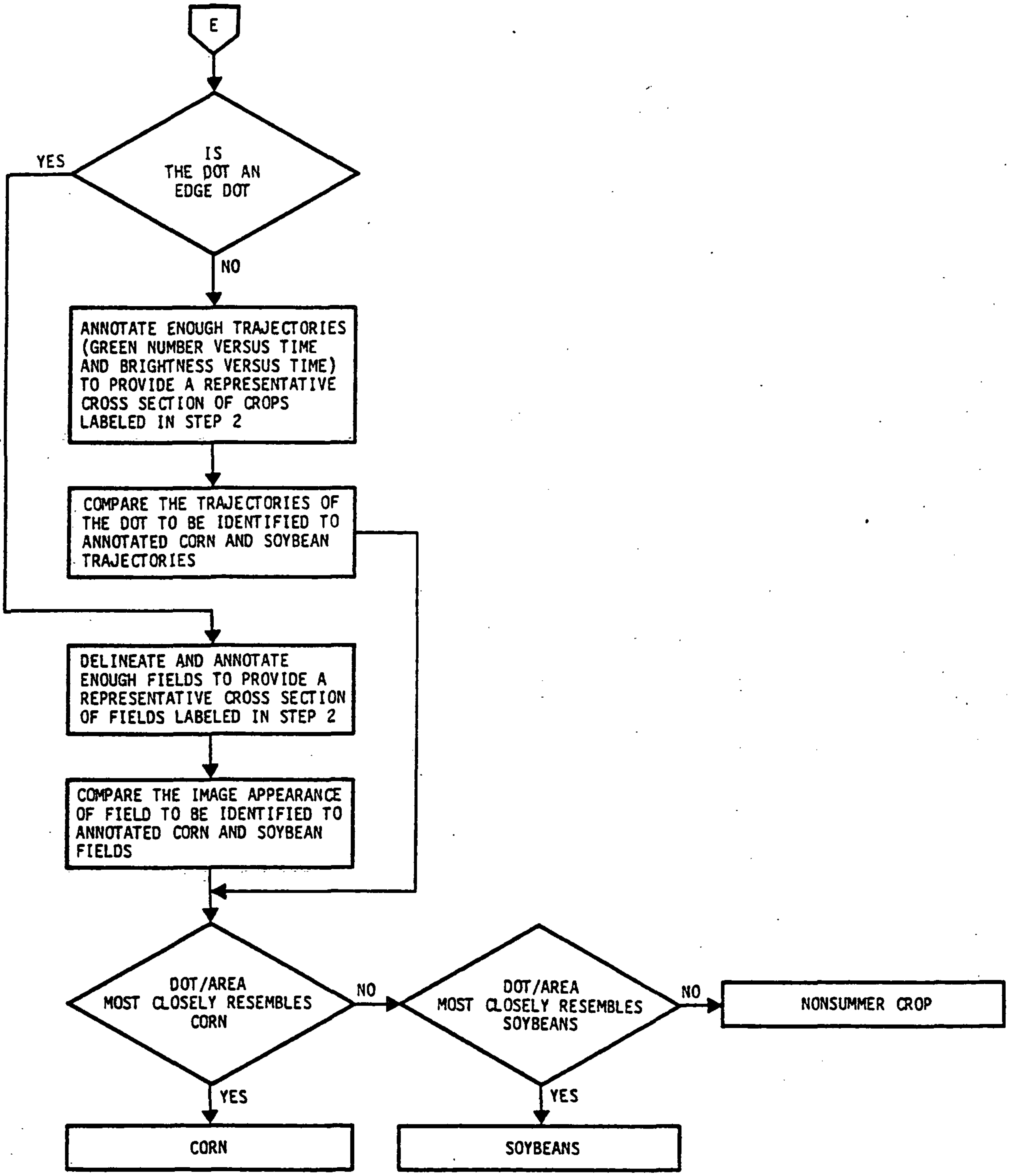


Figure 5-7. - Diagram of decision logic for labeling remaining dots (Step 4).

acquisition is compared with areas of known corn and soybeans and labeled according to the area it most closely resembles. Green number and brightness are plotted versus time for all acceptable (cloud- and haze-free) acquisitions to aid the analyst in labeling the dots that fell within the limiters. These time profiles are obtained for all previously labeled and unlabeled samples. In Step 4, the analyst compares corn and soybean profiles labeled from Step 3 with the profiles of the yet unlabeled dots. The unlabeled profiles are then labeled by assigning them the label of the most similar profile.

6. SUMMARY OF TESTS AND RESULTS

The two tests conducted using the corn/soybean decision logic procedure were the Multicrop Exploratory Experiment (ref. 1) and the Simulated Aggregation Test. In the first test, the objectives were to shake down the procedure and to determine if the procedure is analyst dependent. The objectives of the second test were to test the procedure that resulted after modifications based on the first test were included and to provide information such as segment number, location, acquisitions used, defined biowindows, and the separation point for the data sets used is presented in appendix C.

For the multicrop test, a rigid design plan was followed using three groups of analysts and preselected segments and acquisitions. Each segment was worked by at least two groups. In the simulated aggregation test, three analyst teams (group I, group II, and group III) were responsible for doing the entire labeling procedure including segment and acquisition selection. Of the 100 segments designated for the test, 88 met the labeling criteria. Each segment was labeled only once. Included in the second test were 23 segments from the first test which were relabeled by a new analyst team.

Overall labeling accuracies comparing analyst labels to pure small-dot ground-truth labels (ref. 9) for each test are presented in table 6-1. The better accuracies in the second test are attributed to improvements made to the procedure based on results from the first test. Also, the analyst labeled approximately 60 spectrally pure dots as opposed to approximately 140 spectrally mixed or pure dots for which labeling was required in the first test.

Although no significant difference was found, a comparison of the labeling accuracies in table 6-2 shows that the proportion of correct labels at the segment level was generally better in the second test.

During the second test, only acquisitions within a biowindow were used, and two to four acquisitions were acceptable. Preselected acquisitions used in the Multicrop Exploratory Experiment provided less than optimum data for some

TABLE 6-1.- LABELING ACCURACY FOR ANALYST LABELS COMPARED TO PURE SMALL-DOT GROUND-TRUTH LABELS[a]

Test	Accuracy[b]			Commission[b]			Ommission[b]			Confusion[b]	
	P(C/C)	P(Y/Y)	P(O/O)	P(C/O)	P(Y/O)	P(C or Y/O)	P(O/C)	P(O/Y)	P(O/C or Y)	P(C/Y)	P(Y/C)
Multicrop Exploratory Experiment	82.4	74.8	91.2	6.4	6.4	8.8	13.3	13.9	13.7	10.6	4.1
Simulated Aggregation Test	92.5	87.6	95.9	2.9	1.1	4.0	5.8	5.5	5.6	6.7	1.6

[a]Codes are C for Corn, Y for soybeans, and O for "other."

[b]For example, subhead P(C/C) refers to the proportion of corn to corn.

TABLE 6-2.- LABELING ACCURACY FOR TWENTY-THREE SEGMENTS PROCESSED IN BOTH TESTS

Segment	Corn				Soybeans				Other			
	Multicrop Exploratory Experiment			Simulated Aggregation Test	Multicrop Exploratory Experiment			Simulated Aggregation Test	Multicrop Exploratory Experiment			Simulated Aggregation Test
	Group I	Group II	Group III		Group I	Group II	Group III		Group I	Group II	Group III	
107	88.9	90.9		88.9	90.9	90.5		100.0	42.9	66.7		25.0
123	65.7	64.7		71.4	92.9	89.5		100.0	96.9	100.0		100.0
127	93.3	90.0	78.8	89.7	77.1	70.6	76.5	73.7	100.0	100.0	92.9	100.0
133		64.5*	25.9*	88.9		46.2*	23.1*	66.7		94.9*	97.7*	90.3
135	67.3		67.3	96.0	76.2		71.4	100.0	93.8		88.2	85.7
141	90.9		71.4	93.8	88.2		93.8	66.7	100.0		92.7	81.2
144		81.0	90.5	91.7		28.6	60.0	62.5		93.0	94.9	96.6
205	72.2	82.4		58.3	62.7	64.2		81.8	100.0	95.5		90.0
800	91.5	93.4		74.4	75.9	77.8		88.9	100.0	100.0		100.0
809	93.8		93.9	100.0	69.2		72.7	100.0	76.5		73.3	100.0
832	85.7		62.5	85.7	71.1		63.4	69.2	87.5		91.3	92.3
837	100.0	95.2	95.2	100.0	63.0	80.4	87.2	78.6	94.4	94.1	100.0	100.0
842	78.0	84.6		82.4	92.1	97.1		75.0	100.0	92.9		100.0
843	88.9	96.8		85.0	82.8	92.9		83.3	94.7	100.0		100.0
852	85.7		82.6	88.9	82.9		64.9	81.8	90.0		93.9	94.4
853	82.4		90.9	83.3	85.7		92.9	86.7	88.5		75.0	100.0
860		87.8	77.8	90.5		54.8	66.7	76.9		96.3	96.0	100.0
864		81.5	80.4	73.1		100.0	88.9	50.0		92.0	70.8	100.0
865	83.8		78.4	100.0	90.0		88.9	57.1	88.2		91.2	90.9
877	86.7	89.1		87.9	61.1	70.6		50.0	84.6	84.6		83.3
880		87.5	80.9	100.0		82.9	82.9	95.2		86.7	69.2	85.7
881	80.4	88.2	63.0	85.7	100.0	77.8	25.0	100.0	100.0	97.8	100.0	100.0
882	98.4	95.4	96.8	96.7	85.3	88.2	90.9	95.5	100.0	100.0	100.0	100.0
$\bar{x}$	85.2	85.8	77.2	87.4	80.3	75.7	71.8	79.9	90.9	93.4	89.1	91.9

*Misregistered data affected labeling accuracy.

segments because they had to be chosen before biowindow definition guidelines had been completed and before retro-ordered acquisitions were available. For example, four acquisitions were required for processing. Therefore, the fourth acquisition usually occurred outside a window, causing confusion because of mixed signatures. In some cases, acquisitions outside a biowindow were used when an equally good or better acquisition was available in the biowindow. This improvement to the test design may explain in part the better accuracies observed in the second test.

Other trends were observed during test evaluation. One observation from the first test was that, from the first to the second time a segment was labeled, accuracies increased 74 percent of the time for corn and 56 percent of the time for soybeans. This indicates that, as the analyst becomes more familiar with procedures, labeling accuracy may improve.

The labeling accuracy of group III for corn was significantly different when compared to the accuracy obtained by other groups (ref. 1). For some segments, group III picked a different separation date or differed the placement of the separation point on the scatter plot. In those cases, the inconsistencies had a definite effect on the correct identification of corn and soybeans. The overall labeling accuracies were affected negatively by this group effect.

Some problems with the procedure were identified in the procedure control reports (refs. 10 and 11) as follows:

- Although biowindow definitions were considered to be straight forward, biowindow ranges determined by two different teams sometimes varied as much as 20 days. The primary reason for the discrepancies was related to the use of the crop calendar shown in figure 6-1. This presentation of crop calendar information, depicting 10-day intervals, was not conducive to defining biowindow ranges consistently. Differences in biowindow length could seriously affect the acquisition selection.

Soybeans: Stages 2, 3, 4, and 5 were interpolated.

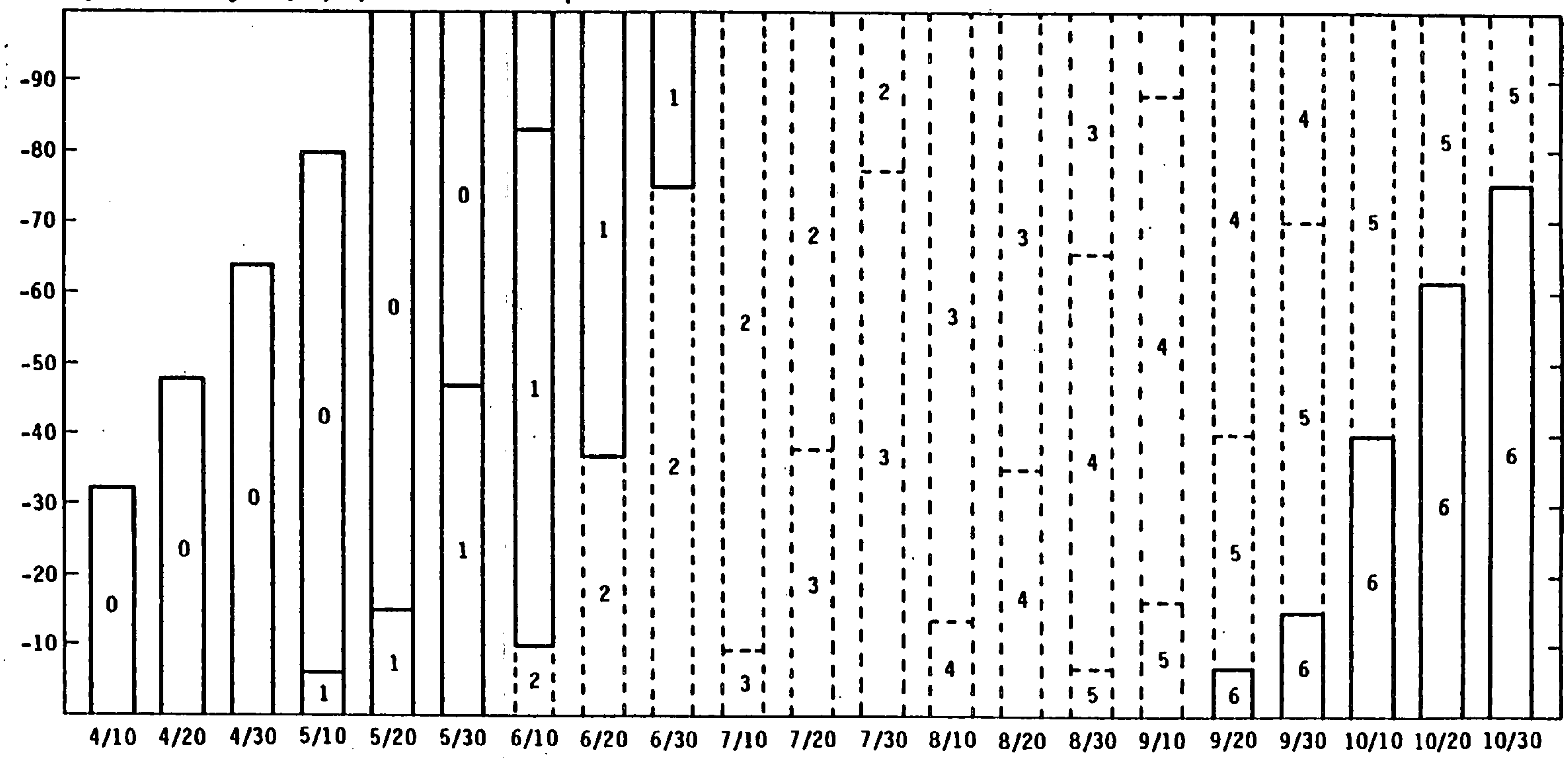


Figure 6-1.- Bar graph crop calendar.

- The spatial and color determinations which were made from the imagery introduce subjective judgments into the procedure. Identification of mixed and misregistered pixels was a difficult task to accomplish. Inconsistency was observed at two different times: by the same individual at different times and between individuals. Color determinations also differed from analyst to analyst.

- Currently, the decision logic only identifies the normal corn/soybean growth cycles. Deviations caused by double cropping, episodal events, and late and early planting were not accounted for in the decision logic.

In summary, the corn/soybean decision logic procedure was easily learned and implemented by both experienced and inexperienced analysts. The amount of time necessary to do the procedure compared favorably with other procedures. Quality assurance (Procedures Control) and error characterization functions were objective because the decision logic was systematic enough that diagnostics could be readily applied to identify the steps where labeling problems occurred. Steps which required changes and/or modifications were recognized readily. In addition, several parts of the decision logic, particularly Steps 2, 3, and 4, could be automated.

7. RECOMMENDATIONS

In order to refine the current decision logic, various actions should be undertaken:

- Normal (historical) crop calendars, which often contained interpolated data and represented only two to five years of information, should be expanded to increase reliability and should have a standard format to allow for consistent definition of biowindow ranges. Current year crop calendar information and adjustable growth models would aid in future development and more accurate biowindow definitions.
- Further study is needed to determine if incorporation of spectral aids into Step 1 and Step 2 could alleviate some of the current inconsistencies in those steps.
- Proceed to automate various parts of the decision logic. Some of the subjective decisions that an analyst is forced to make could be alleviated by using a boundary detection algorithm (i.e., BLOB, ref. 12) and a curve comparison routine (i.e., Badhwar, ref. 13). Both the biowindow definitions and the scatter plot break are conducive to automation. If a color determination scheme (i.e., Cate's color model, ref. 14) were incorporated into the procedure, then Steps 2, 3, and 4 could be completely computerized.

The corn/soybean decision logic has produced encouraging results in the U.S. Corn Belt. Further study should be done to determine if this procedure can be extended to other geographic locations. Also investigations should be done to determine if this method of crop labeling can be expanded to other crops.

8. REFERENCES

1. Carnes, J. and Baird, E.: Evaluation of Results from the U.S. Corn and Soybean Exploratory Experiment. FC-LO-00423, JSC-16339, LEMSCO-14386, July 1980.

2. GSFC: Landsat Data User's Handbook. Document number 76SDS4258 (Greenbelt, Maryland), September 1976.

3. Kauth, R. J.; and Thomas G. S.: The Tasselled Cap - A Graphic Description of the Spectral-Temporal Development of Agricultural Crops As Seen By Landsat. Proceedings of Tenth Annual Symposium on Remote Sensing of Environment (Ann Arbor, Michigan), October 1-2, 1975.

4. Wehmanen, O. A.: The Structure of Landsat Data for Wheat-Growing Region. LEC-13015, January, 1979.

5. Palmer, W.: Multicrop Labeling Decision Logic. Report generated for action document 63-1827-4845-27.

6. Detailed Analysis Procedures for Transition Project (FY 79). LACIE-00724, JSC-13756, May 1979.

7. Dailey, C.; Abotteen, K.: Corn/Soybean Spectral Aid Study. Report generated for action document 63-1287-4845-23.

8. Anderson, J. R.; Hardy, E. E.; Roach, J. T.; and Witmer, R. E.: Land Use and Land Cover Classification System for Use With Remote Sensing Data, Geological Survey Professional Paper 964. Department of the Interior, United States Government Printing Office, Washington, D.C., 1976.

9. White, T.: Dot Method of Digitized Ground Inventory Information. Earth Observations Division, Lyndon B. Johnson Space Center (Houston, Texas), February 1979.

10. Dailey, C. L.; and Abotteen, K. M.: Procedures Control Report - Simulated Aggregation Test. Report issued under action document 63-1287-4845-48.

11. Abotteen, K. M.; and Dailey, C. L.: Procedures Control Report - Multicrop Exploratory Experiment. Report issued under action document 63-1287-4845-23.

12. Kauth, R. J.; Pentland, A. P.; and Thomas, G. S.: BLOB, An Unsupervised Clustering Approach to Spatial Preprocessing of MSS Imagery, Eleventh International Symposium on Remote Sensing of Environment, Environmental Research Institute of Michigan (Ann Arbor, Michigan), vol. 2, 1977, pp. 1309-1317.

13. Badhwar, G.: A Semi-Automatic Technique for Multitemporal Classification of a Given Crop. NASA/JSC Report - (to be published).

14. Cate, R. B.; Phinney, D. E.; Kinsler, M. C.; Sestak, M. L.; Hodges, T.; and Dishler, J. J.; Interpretation of Landsat Digital Data Using a Cubic Color Model Based On Relative Energies. SR-L0-00418, JSC-13776, LEMSCO-13499, February 1980.

APPENDIX A.

OBSERVED CHARACTERISTICS OF CORN AND SOYBEANS

APPENDIX A

OBSERVED CHARACTERISTICS OF CORN AND SOYBEANS

The characteristics of corn and soybeans which were observed on the development segments are presented in tables A-1 through A-4.

For both crops, the growth stages corresponding to each acquisition are presented in terms of historical data and current-year observations. The historical growth stages are taken from CRD normal crop calendars. The observed growth stages are taken from segment crop calendars that were constructed from actual field observations collected for approximately 10 fields per segment at various times throughout the growing season.

In tables A-1 through A-4, image appearance refers to colors observed on the Product 1. The green number and brightness for corn and soybeans are presented in terms of the means and standard deviations of pure pixels.

TABLE A-1a.- OBSERVED CHARACTERISTICS OF CORN AND SOYBEANS AS A FUNCTION OF GROWTH STAGE, APU 14

For Segment 892:	June 16	July 23	Aug. 9	Sept. 4	Sept. 23	Oct. 20
Corn						
Growth stage (historical)	70%>2	60%>3	85%>3	70%>5	75%>5	20%>6
Growth stage (observed)		30%>3	100%>3	50%>5	55%>5	50%>6
Image appearance	Green, lt. red	Red	Dull red, brown	Green, brown, purple	Brown, purple, green, white	Yellow, green, white
Green number	8±3.4	25±3.4	61±2.2	7±1.9	9±2.8	4±1.3
Brightness	78±6.9	57±10.1	61±2.2	43±2.6	41±4.2	40±8.4
Soybeans						
Growth stage (historical)	30%>2	20%>3	65%>3	60%>5	65%>5	60%>6
Growth stage (observed)		100%>2	65%>2	10%>5	10%>5	100%>6
Image appearance	Green	Red	Br. red	Yellow, pink, green	Yellow, pink, green	Green
Green number	6±3.2	31±6.1	43±7	15±9.4	15±8.3	4±2.5
Brightness	83±7.6	67±8.3	83±5.4	56±4.1	54±3.8	44±5

TABLE A-1b.- OBSERVED CHARACTERISTICS OF CORN AND SOYBEANS AS A FUNCTION OF GROWTH STAGE, APU 14

For Segment 886:	June 16	July 23	July 31	Sept. 6	Sept. 15	Sept. 24	Oct. 20	Nov. 7
Corn								
Growth stage (historical)	80%>2	45%>3	75%>31	60%>4 25%>5	80%>4 50%>5	75%>5	20%>6	50%>6
Growth stage (observed)		90%>3	100%>3	100%>4	25%>5	85%>5	30%>6	85%>6
Image appearance	Green	Red	Dull red, brown	Dull red, brown	Green, white, brown	Green, brown, white	Green, white	Green, white
Green number	9±2.1	27±2.1	22±2.3	15±2.3	12±2.7	7±2.3	4±1.2	3±1.9
Brightness	68±5.8	58±3.4	67±4.9	55±2.9	44±2.8	39±2.6	43±7.6	42±8.1
Soybeans								
Growth stage (historical)	90%>1	100%>2	20%>3	75%>4	20%>5	50%>5	50%>6	100%>6
Growth stage (observed)		100%>2	10%>3	100%>4	15%>5	85%>5	100%>6	100%>6
Image appearance	Green	Br. red	Br. red	Br. red	Red, pink	Pink, green	Green, white	Green, white
Green number	6±2.1	32±2.9	35±8.2	33±5.1	25±5.2	12±4.0	3±1.0	2±.6
Brightness	72±4.3	68±4.5	81±8.2	73±3.8	56±6.8	49±2.9	44±7.6	41±2.8

TABLE A-2a.- OBSERVED CHARACTERISTICS OF CORN AND SOYBEANS AS A FUNCTION OF GROWTH STAGE, APU 24

For Segment 804:	June 15	Aug. 17	Sept. 4	Sept. 22	Oct. 1	Oct. 19
Corn						
Growth stage (historical)	65%>2	85%>3	50%>4	65%>5	90%>5	15%>6
Growth stage (observed)		100%>3	100%>4	90%>5	20%>6	86%>6
Image appearance	Green, red	Red, brown	Red, brown	Green, purple		
Green number	8±2.7	12±2.6	7±2.4	3±1.8	3±1.9	3±1.5
Brightness	46±6.7	56±1.9	51±3.5	36±2.9	38±11.9	43±8.1
Soybeans						
Growth stage (historical)	25%>2	60%>3	70%>4	30%>5	85%>5	50%>6
Growth stage (observed)		100%>3	100%>4	80%>5	45%>6	100%>6
Image appearance	Green	Br. red, orange	Br. red, pink	Yellow, pink, green	Yellow, pink, green	Green, brown
Green number	5±2.8	31±5.0	18±5.9	7±4.1	5±2.0	2±1.0
Brightness	43±5.4	77±4.3	69±4.3	43±3.4	46±7.5	41±3.3

TABLE A-2B.- OBSERVED CHARACTERISTICS OF CORN AND SOYBEANS AS A FUNCTION OF GROWTH STAGE, APU 24

For Segment 883:	July 5	July 23	Aug. 8	Aug. 9	Aug. 10	Sept. 24	Oct. 20	Oct. 30
Corn								
Growth stage (historical)	90%>3	100%>3	100%>3	100%>3	15%>4	75%>5	30%>6	60%>6
Growth stage (observed)		90%>3	100%>3	100%>3	100%>3	50%>5	40%>6	90%>6
Image appearance	Red, brown	Red, brown	Red, brown	Red, brown	Red, brown	Green, brown	Green, white	Brown, white, green, yellow
Green number	25±4.8	24±3.5	20±3.7	19±2.8	19±3.0	6±2.5	5±1.8	5±1.7
Brightness	64±3.6	61±3.2	66±3.3	60±3.3	57±3.6	40±4.2	43±8.0	41±8.2
Soybeans								
Growth stgae (historical)	90%>2	35%>3	55%>3	80%>3	85%>3	75%>5	75%>6	95%>6
Growth stage (observed)		100%>2	10%>3	55%>3	60%>3	50%>5	80%>6	95%>6
Image appearance	Red, brown	Br. red	Br. red	Br. red	Br. red	Green, brown	Green, brown	Green, brown
Green number	16±4.0	31±5.5	36±3.4	37±3.9	36±4.5	4±5.0	3±1.3	3±1.0
Brightness	58±3.6	67±4.2	79±4.3	73±3.7	70±6.0	41±2.6	36±8.2	32±6.5

TABLE A-3a.- OBSERVED CHARACTERISTICS OF CORN AND SOYBEANS AS A FUNCTION OF GROWTH STAGE, APU 25

For Segment 209:	June 16	July 4	July 31	Aug. 8	Aug. 9	Sept. 4	Sept. 22	Sept. 23	Oct. 1	Oct. 19	Oct. 20
Corn											
Growth stage (historical)	90%>2	70%>3	25%>4	50%>4	55%>4	50%>5	75%>5	80%>5		55%>6	60%>6
Growth stage (observed)											
Image appearance	Green	Green, white	Red, brown	Red, brown	Red, brown	Dull purple	Dull purple	Dull purple	Brown, green	Green, white	Green white
Green number	3±6.5	12±6.5			28±4.6	18±1.8		11±1.5	12±2.3	3±1.8	
Brightness	66±3.5	80±2.6			62±4.6	46±1.9	36±3.4	44±3.7	40±3.5		
Soybeans											
Growth stage (historical)	60%>2	100%>2	35%>3	55%>3	60%>3	55%>4	40%>5	45%>5	70%>5	50%>6	55%>6
Growth stage (observed)							10%>6	15%>6	20%>6		
Image appearance	Green	Green	Pink, red, green	Pink, red, purple	Pink, red, purple	Br. red	Br. red, pink	Br. red, pink	Pink, green white		
Green number	70±1.3	7±1.5	19±.6	29±2.5	38±2.3	27±1.5		22±1.1	21±4.3	3±.5	3±.5
Brightness	6-15	93±3.5	55±1.7	86±1.2	79±2.0	57±.4		50±1.5	70±3.0	45±1.9	44±2.5

TABLE A-3b.- OBSERVED CHARACTERISTICS OF CORN AND SOYBEANS AS A FUNCTION OF GROWTH STAGE, APU 25

For Segment 211:	June 15	July 3	July 21	Aug. 8	Sept. 4	Sept. 22	Oct. 1	Oct. 19	Oct. 28
Corn									
Growth stage (historical)	90%>2	35%>3	80%>3	45%>4	35%>5	70%>5	35%>6	50%>6	60%>6
Growth stage (observed)		100%>2	45%>3	100%>3	100%>4	25%>5	10%>6	35%>6	45%>6
Image appearance	Green	Green, white	Green, red	Red, brown	Purple, brown	Green, brown	Green, brown	Green, brown	Green
Green number	1±3.8	14±6.0	19±3.1		20±2.5	10±1.8	5±2.0	1±1.6	
Brightness	76±6.1	61±5.1	68±3.3		50±2.6	38±2.1	35±4.0	31±3.2	
Soybeans									
Growth stage (historical)	50%>2	100%>2	15%>3	55%>3	60%>4	35%>5	65%>5 20%>6	90%>5 45%>6	60%>6
Growth stage (observed)		100%>2	100%>2	100%>2	90%>3	30%>4	10%>5	25%>5	65%>6
Image appearance	Green	Green, white	Green, red	Br. red, brown	Br. red	Br. red, pink	Pink, green, brown	Green white	Green
Green number	6±1.6	7±2.6	10±2.0	18±2.6	27±2.9	24±2.1	13±2.0	4±.7	1±1.1
Brightness	76±2.2	72±6.7	67±2.1	73±2.4	65±2.8	62±3.4	48±1.7	37±5.5	37±1.8

TABLE A-4a.- OBSERVED CHARACTERISTICS OF CORN AND SOYBEANS AS A FUNCTION OF GROWTH STAGE, APU 28

For Segment 824:	June 12	Aug. 5	Aug. 23	Aug. 31	Sept. 1	Sept. 19	Sept. 28	Nov. 2	Nov. 3
Corn									
Growth stage (historical)	75%>2	70%>3	35%>4	45%>4	50%>4	35%>5	50%>5	60%>6	65%>6
Growth stage (observed)		100%>3	75%>4	100%>4	100%>4	35%>5	20%>6	10%>6	100%>6
Image appearance	Red green	Red, brown, purple	Red, brown, purple	Red, brown, purple	Red, brown, green	Purple, green	Brown, green, white	Brown, green, white	Brown, green, white
Green number	7±3.1	15±3.0	12±3.3	11±4.9	8±2.5	5±2.5	5±1.5	3±.8	3±1.1
Brightness	45±6.0	63±3.2	61±3.2	54±3.3	60±3.1	42±4.4	31±3.8	21±3.8	21±4.6
Soybeans									
Growth stage (historical)	25%>2	65%>3	55%>4	75%>4	80%>4	70%>5	85%>5	100%>6	100%>6
Growth stage (observed)		55%>3	40%>4	75%>4	80%>4	75%>5	70%>6	100%>6	100%>6
Image appearance	Brown, purple	Pink, red, orange	Br. red, orange	Br. red, orange	Br. red, orange	Pink, green, white	Brown, green, white	Brown, grey	Brown, grey
Green number	4±1.6	26±6.9	28±4.3	24±6.1	20±5.6	3±1.9	4±2.0	3±1.1	3±1.1
Brightness	42±9.4	75±5.4	76±4.7	70±3.9	73±3.1	45±3.1	47±11.9	22±5.1	22±5.1

TABLE A-4b.- OBSERVED CHARACTERISTICS OF CORN AND SOYBEANS AS A FUNCTION OF GROWTH STAGE, APU 28

For Segment 854:	June 10	July 26	Aug. 4	Aug. 21	Aug. 22	Aug. 31	Sept. 8	Sept. 9	Sept. 26	Sept. 27	Nov. 2	Dec. 17
Corn												
Growth stage (historical)	30%>2	50%>3	75%>4	45%>4	45%>4	90%>4 10%>5	15%>5	20%>5	65%>5	70%>5	50%>6	100%>6
Growth stage (observed)		50%>3	100%>3	80%>4	85%>4	100%>4	100%>4	5%>5	30%>6	35%>6	100%>6	100%>6
Image appearance	Green	Red, brown	Red, brown	Red, brown	Red, brown	Red, brown, purple	Red, brown, purple	Red, brown, green	Red, brown, green	Red, brown, green	Gray, green	Gray
Green number	5±2.1	28±3.6	25±2.8	17±2.1	16±2.0	13±3.9	14±1.8	12±1.6	8±2.1	8±1.9	3±1.2	3±.9
Brightness	73±13.0	67±3.7	61±3.3	56±2.4	54±2.2	52±2.6	55±2.3	54±1.8	42±2.0	44±2.0	31±10.8	18±4.5
Soybeans												
Growth stage (historical)	15%>2	65%>3	100%>3	75%>4	80%>4	15%>5	30%>5	35%>5	20%>6	25%>6	90%>6	100%>6
Growth stage (observed)		100%>2	40%>3	25%>4	30%>4	100%>4	100%>4	100%>4	70%>5	75%>5	100%>6	100%>6
Image appearance	Green	Red, orange	Red, orange	Br. red, orange	Br. red, orange	Red	Br. red	Br. red	Pink, green, brown	Pink, green, brown	Green, brown	Gray
Green number	5±1.7	17±6.7	30±9.8	36±7.3	34±4.5	31±4.9	32±3.6	27±3.9	10±3.9	8±3.2	2±1.0	3±1.1
Brightness	61±12.7	66±6.2	68±8.3	76±6.8	70±4.2	70±5.3	70±3.9	69±3.1	51±3.6	50±2.4	30±6.6	17±2.7

APPENDIX B

DEFINITIONS AND CHARACTERISTICS OF DECISION-TREE CATEGORIES

APPENDIX B

DEFINITIONS AND CHARACTERISTICS OF DECISION-TREE CATEGORIES

B.1 RANGE

Range is uncultivated land that produces forage suitable for livestock grazing. Generally, it is land that is not suited for other types of agriculture, and the natural vegetation consists of predominantly grasslike plants, forbs, or shrubs. Most range in the United States is west of a north-south line that cuts through North and South Dakota, Nebraska, Kansas, Oklahoma, and Texas.

Characteristics:

1. Large and irregular in the Western United States
2. Vegetation indication varied, both within a specific area and between different areas; permanent, with some seasonal change
3. No planting or harvest
4. Coarse texture
5. Red-brown to red in summer and a shade of gray in winter
6. Can occur in conjunction with and adjacent to cropland
7. Best detected in spring

B.2 PASTURE

A pasture is a fenced or unfenced tract of land on which farm animals feed by grazing. Generally, it is a grass area, but it may also have brush and trees. This land category includes land used for feeding at a specific time in rotation with other uses; therefore, land in this situation could be pasture one year and cropland the next. It must be emphasized that the distinction between pasture and range is one of degree and location rather than of actual difference in use. Some definitions of pasture list range as a synonymous term.

Characteristics:

1. Shape varied; geometrical in Eastern and Central United States
2. Size small in Eastern United States, becoming larger westward
3. Easily confused with range
4. Color varied and mixed, ranging from mottled light pink or gray-brown to bright red on highly improved pastures
5. Seasonal changes; no planting or harvest unless new pasture being initiated or old one destroyed
6. Best detected in spring

B.3 ORCHARDS

An area or enclosure devoted to growing fruit, nuts, or certain forest products either as a commercial crop or for reseeding is categorized as an orchard. Isolated small enclosures used for these purposes on small farms would not be recognizable on Landsat imagery.

<u>Characteristics:</u>

1. Varied appearance, depending upon such variables as type of trees, spacing, age, canopy, time of year, and farming practices
2. May closely resemble forest — bright red in late spring and early summer, red-brown at other times
3. Size small in relation to forests
4. Shape and pattern generally regular
5. Area extent usually constant over long time periods

B.4 FOREST

A forest is a plant association predominantly of trees and other woody vegetation that occupies a rather extensive area.

Characteristics:

1. Shape, pattern, and size irregular
2. Generally follows terrain and drainage
3. No planting or harvest as with crops, but annual loss of leafage by certain trees
4. Area extent usually constant over long time periods
5. Bright red in late spring and early summer and reddish brown at other times; variation in intensity and shade

B.5 URBAN

This category is composed of areas that have much of the land covered by structures. It includes villages, towns, cities, strip developments, transportation and industrial areas, shopping centers, parks, cemeteries, golf courses, and sewage plants, as well as institutions that may, in some instances, be isolated from the main urban area. It also includes those areas that strictly are not urban but have been surrounded by urban development.

Characteristics:

1. Irregular in shape and area extent
2. Grid pattern within urban boundaries
3. White to a mixed mottled steel blue; constant through time
4. Texture usually extremely fine
5. Possible occurrence of irregularly shaped areas of light pink to medium red within urban area
6. Close correlation of pattern with urban outline on map
7. Transportation network associated with urban area basically white; can be constant through time

B.6 BARREN LAND

Barren land has a limited ability to support life. Generally, this is an area of thin soil, sand, or rock. Vegetation, if present, is more widely spaced and scrubby than that in the range category. Within this category are dry salt flats, sandy areas other than beaches, exposed rock, and extractive activities (e.g., strip mines, borrow pits, and gravel pits — either active or inactive) having significant surface expression (area).

Characteristics:

1. Bright and constant throughout year
2. Varied dark and light colors and tones
3. Irregular shape
4. Little or no vegetation
5. Size varied, ranging from minute (1 pixel) to extreme (1000 pixels or more)
6. No seasonal change in shape and size

B.7 OTHER AGRICULTURAL LAND

This category is for those items not classified under separate agricultural categories. It includes farmsteads, farm lanes and roads, ditches, horse farms, confined feeding operations such as beef cattle and swine feedlots, dairy operations, and large poultry farms. Generally, these items are small in area, and it is doubtful that items of this nature can be interpreted on Landsat imagery as being other than a farm or farmstead.

<u>Characteristics:</u>

1. Color extremely varied and mixed, white to a dirty or off white for farmsteads and related activities
2. Area extent small
3. No green vegetation
4. No planting or harvest
5. Can occur in conjunction with and adjacent to cropland

B.8 WATER

This category refers to those areas persistently water covered. It includes rivers, streams, canals, lakes (natural and manmade), reservoirs, and bays and estuaries that extend inland.

Characteristics:

1. Irregular in shape except in some cases where manmade
2. May change slightly in shape and size during year
3. Should closely resemble shape and size on map, if mapped
4. Color varied, ranging from a dark blue-black to a bright blue, but usually some shade of blue throughout year
5. Smooth and uniform texture
6. No vegetation

B.9 CROPLAND

Cropland includes all land tilled for crops, as well as cultivated wetlands such as the flooded fields associated with rice production and developed cranberry bogs.

Characteristics:

1. Distinctive geometric field and road pattern in Central and Western United States; irregular and unsystematic in Eastern United States
2. Definite seasonal and intraseasonal changes in color; generally some shade of red or red-brown during growing season
3. Variation in color and intensity with crop type
4. Planting and harvest
5. Vegetation present but not permanent
6. Best detected in summer and early fall

B.10 FALLOW

This is cultivated land that may be kept free of vegetation by such methods as plowing and disking in order to destroy weeds or to conserve a supply of moisture for a succeeding crop.

<u>Characteristics:</u>

1. Shape and pattern similar to areas identified as cropland
2. Planting or harvest
3. Constant blue-green in color, but may vary from dark to light during year

B.11 WETLANDS

Areas where the water table is at, near, or above the land surface for a significant part of most years are categorized as wetlands. This category includes marshes, swamps, and tidal flats along the shallow margins of bays, lakes, rivers, and manmade impoundments or reservoirs, bogs, wet meadows, seasonally wet or flooded basins, playas, potholes, and wetland used for wildlife purposes. It does not include wetlands drained for any purpose or wetlands used for rice or similar types of production; these belong to other categories. Wetlands can be either forested or unforested.

Characteristics:

1. Highly varied appearance, both in color and intensity, depending upon such variables as vegetation type, wet or dry season, and winter or summer
2. Irregular in size and shape; not similar to areas identified as cropland
3. Intermittent water possible during year
4. No planting or harvest
5. Seasonally wet

APPENDIX C

DATA SETS USED IN TESTING

APPENDIX C

DATA SETS USED IN TESTING

The following tables contain the segment numbers, the state, and the APU in which the segment is located, the separation acquisition, the acquisitions used for batch processing, the biowindow ranges, the number of available acquisitions in each biowindow and the green number-brightness break in the data on the separation acquisition for all of the segments processed. Table C-1 shows the data set for the Multicrop Exploratory Experiment. Table C-2 shows the data set used in the Simulated Aggregation Test.

TABLE C-1.- DATA SET FOR THE MULTICROP EXPLORATORY EXPERIMENT

Segment number	State/APU	Separation date	Acquisitions processed				Biowindow range (no. of acquisitions)				Scatter plot break
			Base date	2	3	4	A	B	C	Separation	
107A	Ill./25	8235	8235	8208	8262	8307	(0) 144-163	(3) 207-250	(1) 300-337	(3) 221-250	31-69
[a]107B		8235	8235				(0) 145-150	(3) 205-246	(1) 297-335	(3) 220-246	30-69
123A	Ind./28	8233	8233	8161	8197	8305	(2) 146-163	(1) 208-244	(1) 283-337	(1) 223-244	37-70
123B		8233	8233				(2) 144-162	(1) 206-246	(1) 285-336	(1) 223-246	37-68
127A	Ind./28	8243	8243	8161	8269	8306	(2) 150-161	(3) 212-253	(4) 283-365	(2) 222-253	23-60
127B		8243	8243				(2) 147-161	(2) 211-243	(3) 293-334	(1) 222-243	27-65
127C		8216	8243				(2) 145-161	(2) 210-243	(3) 280-335	(1) 222-243	33-73
[b]133A	Ind./28	8233	8233	8152	8269	8314	(1) 145-161	(1) 211-242	(0) 293-345	(1) 227-242	31-67
133B		8233	8233				(1) 150-161	(1) 222-242	(0) 293-334	(1) 232-242	31-66
135A	Iowa/24	8247	8247	8130	8229	8292	(1) 146-166	(2) 210-252	(0) 312-351	(2) 225-252	18-61
135B		8247	8247				(0) 147-150	(2) 210-252	(0) 312-340	(2) 228-254	18-60
141A	Iowa/25	8221	8265	8186	8221	[c]8292	(0) 144-150	(3) 209-258	(1) 306-342	(2) 222-258	23-67

[a]The base date and acquisitions 2, 3, and 4 are the same for each processing.
[b]A misregistered date (8292) caused inaccurate labeling of this segment.
[c]Other acquisitions were available within a biowindow range.

TABLE C-1.- Continued.

Segment number	State/APU	Separation date	Acquisitions processed				Biowindow range (no. of acquisitions)				Scatter plot break
			Base date	2	3	4	A	B	C	Separation	
141B		8221	8265				(1) 144-169	(2) 207-254	(1) 309-346	(1) 222-254	30-75
144A	Iowa/25	8219	8246	8130	8264	8292*	(0) 145-147	(2) 207-240	(1) 309-336	(1) 222-240	36-76
144B		8246	8246				(0) 147-150	(3) 207-246	(2) 300-339	(2) 222-246	20-60
**202A	Mo./14	8221	8167	8221	8266*	8293	(0) 135-150	(2) 206-244	(3) 298-334	(1) 217-244	28-75
202B		8266	8167				(0) 140-150	(2) 211-252	(2) 303-354	(0) 222-252	24-60
202C		8221	8167				(0) 137-148	(2) 203-245	(4) 293-342	(1) 218-245	29-76
205A	Mo./25	8218	8218	8164	8246	8290*	(0) 142-150	(2) 201-243	(2) 295-355	(0) 224-243	36-66
205B		8218	8218				(0) 140-150	(3) 200-250	(2) 293-334	(1) 222-250	36-66
**216A	Mo./25	8220	8220	8130	8247	8292	(0) 140-150	(2) 201-245	(0) 303-354	(2) 209-245	29-68
216B		8238	8220				(0) 140-150	(3) 201-253	(0) 303-354	(2) 232-253	26-65
800A	Iowa/25	8218	8218	8164	8247	8290*	(1) 144-165	(2) 207-247	(1) 309-339	(1) 230-247	29-70
800B		8218	8218				(0) 147-161	(2) 207-251	(1) 309-339	(1) 229-251	29-68

*Other acquisitions were available within a biowindow range.
**These segments were not used in further testing due to lack of a minimum data set.

TABLE C-1.- Continued.

Segment number	State/APU	Separation date	Acquisitions processed				Biowindow range (no. of acquisitions)				Scatter plot break
			Base date	2	3	4	A	B	C	Separation	
**807A	Ill./25	8218	8290*	8164	8218	8272	(0) 140-161	(1) 211-242	(2) 293-334	(0) 222-242	22-59
807B		8218	8290				(0) 142-157	(1) 206-247	(2) 293-334	(0) 224-244	29-68
809A	Ill./25	8218	8218	8164	8244	8290*	(0) 140-161	(2) 211-253	(2) 293-334	(1) 222-253	34-64
809B		8218	8218				(0) 141-160	(2) 206-250	(2) 291-332	(1) 222-250	36-65
832A	Ind./28	8232	8232	8160	8268*	8304	(2) 150-161	(1) 222-242	(2) 293-334	(1) 232-242	32-61
832B		8232	8232				(2) 145-161	(1) 213-244	(2) 285-344	(1) 228-243	34-65
837A	Ind./28	8251	8270*	8180	8198	8234	(0) 150-161	(5) 211-253	(1) 283-334	(4) 222-253	22-62
837B		8234	8270				(0) 145-161	(5) 206-244	(1) 284-334	(3) 223-244	24-67
837C		8234	8270				(0) 145-161	(4) 208-247	(1) 283-334	(3) 223-247	23-66
842A	Ind./28	8232	8268*	8160	8232	8304	(1) 144-162	(1) 208-249	(3) 288-334	(1) 209-249	27-68
842B		8232	8268				(1) 148-164	(1) 209-248	(3) 293-354	(1) 227-248	27-68
843A	Ind./28	8232	8232	8160	8197*	8269*	(2) 143-162	(1) 209-249	(2) 291-342	(1) 227-249	31-68

*Other acquisitions were available within a biowindow range.
**These segments were not used in further testing due to lack of a minimum data set.

TABLE C-1.- Continued.

Segment number	State/APU	Separation date	Acquisitions processed				Biowindow range (no. of acquisitions)				Scatter plot break
			Base date	2	3	4	A	B	C	Separation	
843B		8232	8232				(2) 146-162	(2) 209-251	(2) 290-343	(2) 224-251	32-69
852A	Ind./28	8232	8232	8160	8268*	8304	(2) 145-163	(2) 211-250	(3) 291-334	(2) 227-250	31-74
852B		8232	8232				(2) 150-171	(2) 211-253	(3) 293-334	(2) 232-253	29-71
853A	Ind./28	8232	8232	8160	8268*	8304	(2) 145-161	(2) 208-250	(2) 293-344	(2) 227-250	28-66
853B		8232	8232				(2) 148-171	(2) 211-253	(2) 293-344	(2) 232-253	26-65
860A	Ind./28	8232	8304	8160	8197*	8232	(2) 147-161	(2) 192-243	(1) 283-342	(1) 227-243	32-65
860B		8251	8304				(2) 150-161	(1) 222-243	(1) 293-334	(1) 232-243	26-59
864A	Iowa/14	8231	8267	8150	8186	8231	(1) 144-156	(3) 207-252	(0) 300-336	(1) 224-252	38-64
864B		8231	8267				(2) 132-159	(2) 210-246	(0) 300-340	(1) 225-246	39-61
865A	Iowa/14	8231	8231	8150	8186*	8267	(2) 141-162	(2) 210-252	(0) 300-342	(2) 225-252	36-63
865B		8231	8231				(1) 144-162	(2) 207-258	(0) 301-345	(2) 225-258	38-62
877A	Iowa/14	8222	8222	8141	8186*	8267*	(2) 141-159	(2) 207-252	(0) 300-336	(2) 222-252	26-64

*Other acquisitions were available within a biowindow range.

TABLE C-1.- Continued.

Segment number	State/APU	Separation date	Acquisitions processed				Biowindow range (no. of acquisitions)				Scatter plot break
			Base date	2	3	4	A	B	C	Separation	
877B		8222	8222				(2) 141-156	(2) 206-248	(0) 297-335	(2) 222-248	28-69
**878A	Iowa/24	8186	8186	8266	8293	8311	(0) 141-150	(0) 207-252	(1) 300-342	(0) 225-252	33-58
878B		8186	8186				(0) 143-160	(0) 208-251	(1) 300-334	(0) 225-251	33-59
880A	Iowa/14	8231	8231	8150	8186	8267	(1) 141-162	(2) 207-252	(1) 300-339	(1) 225-252	36-58
880B		8231	8231				(1) 143-162	(2) 208-262	(1) 300-335	(1) 225-262	37-60
881A	Iowa/14	8222	8222	8141	8186*	8267	(1) 141-162	(2) 210-261	(0) 300-337	(1) 225-252	31-66
881B		8222	8222				(1) 141-160	(2) 208-251	(0) 300-336	(2) 222-251	30-63
881C		8222	8222				(0) 143-159	(2) 208-252	(0) 300-339	(1) 225-252	28-61
882A	Iowa/24	8222	8222	8150	8186*	8293*	(1) 142-157	(3) 207-246	(2) 298-333	(2) 216-246	28-64
882B		8222	8222				(1) 144-159	(3) 207-246	(2) 302-333	(2) 217-246	29-64
882C		8222	8222				(1) 144-160	(3) 211-245	(2) 300-334	(2) 219-245	26-61

*Other acquisitions were available within a biowindow range.
**These segments were not used in further testing due to lack of a minimum data set.

TABLE C-1.- Concluded.

Segment number	State/APU	Separation date	Acquisitions processed				Biowindow range (no. of acquisitions)				Scatter plot break
			Base date	2	3	4	A	B	C	Separation	
**891A	Iowa/14	8249	8258	8168	8168	8267	(0) 150-165	(2) 208-261	(0) 300-345	(1) 220-253	21-67
891B		8249	8258				(0) 144-162	(1) 225-253	(0) 301-344	(1) 225-252	20-65

**These segments were not used in further testing due to lack of a minimum data set.

TABLE C-2.- DATA SET FOR THE SIMULATED AGGREGATION TEST

Segment number	State/APU	Separation date	Acquisitions processed				Biowindow range (no. of acquisitions)				Scatter plot break
			Base date	2	3	4	A	B	C	Separation	
107	Ill./25	8235	8235	8307			(0) 142-161	(5) 204-250	(1) 293-	(4) 217-250	31-68
109	Ill./25	8234	8234	8306			(0) 145-159	(3) 202-234	(1) 288-325	(2) 216-234	26-68
112	Ill./25	8244	3244	8307			(1) 143-159	(4) 206-251	(1) 293-332	(0) 246-251	26-62
113	Ill./25	8235	8235	8307	8163		(2) 140-163	(1) 201-241	(1) 281-323	(1) 211-241	29-73
114	Ill./28	8235	8235	3271	8208		(0) 140-156	(3) 203-239	(1) 286-322	(2) 211-239	26-71
115	Ill./25	8235	8235	8306	8163		(1) 145-159	(4) 203-234	(2) 291-329	(1) 222-234	28-72
120	Ind./28	8233	8233	8306	8161		(1) 145-164	(4) 207-253	(1) 288-344	(2) 225-253	32-69
123	Ind./28	8233	8233	8305	8197	8161	(2) 145-163	(1) 208-245	(1) 283-334	(1) 222-245	28-71
127	Ind./28	8216	8243	8306	8161	8216	(2) 147-161	(2) 210-248	(4) 283-	(1) 225-248	32-72
133	Ind./28	8233	8233	8314	8152		(1) 147-161	(1) 222-242	(0) 293-334	(1) 227-242	35-70
134	Iowa/24	8247	8247	8310	8130		(1) 143-161	(1) 209-247	(1) 300-336	(1) 222-247	23-65
135	Iowa/24	8247	8247	8292	8130		(0) 146-150	(2) 213-261	(0) 310-339	(2) 225-261	17-59
136	Iowa/25	8221	8221	8166	8311		(0) 144-150	(3) 208-255	(1) 306-339	(2) 220-255	34-73
137	Iowa/25	8229	8229	8311	8130		(0) 148-151	(2) 207-252	(3) 303-336	(2) 225-252	26-70

TABLE C-2.- Continued.

Segment number	State/APU	Separation date	Acquisitions processed				Biowindow range (no. of acquisitions)				Scatter plot break
			Base date	2	3	4	A	B	C	Separation	
138	Iowa/25	8246	8246	8300	8156		(1-156) 144-150	(2) 207-240	(0) 303-336	(1) 222-240	23-65
139	Iowa/24	8231	8231	8311	8150		(2) 144-156	(3) 209-249	(2) 306-336	(1) 225-249	27-61
141	Iowa/25	8220	8220	8130	8311		(1-130) 145-150	(2) 206-255	(1) 309-339	(1-220) 222-255	27-70
142	Iowa/24	8231	8231	8303	8141		(1) 138-157	(3) 204-242	(1) 300-332	(2) 216-242	30-59
144	Iowa/25	8246	8246	8300	8130		(0) 142-150	(2) 207-241	(0) 309-336	(1) 223-241	27-69
145	Iowa/25	8220	8220	8311			(0) 144-150	(3) 207-255	(1) 306-339	(3) 222-255	33-69
183	Minn./24	8221	8221	8293			(0) 141-161	(2) 211-259	(3) 283-334	(1) 217-259	32-66
184	Minn./24	8247	8247	8157	8302		(1) 144-158	(4) 205-259	(1) 300-326	(1) 236-259	28-64
201	Mo./25	8220	8220	8292	8138		(0) 140-148	(5) 201-248	(0) 294-363	(3) 221-248	22-65
205	Mo./25	8246	8218	8164	8246	8308	(1-137) (1-164) 140-150	(3) 199-248	(2) 294-359	(1-218) (1-246) 223-248	42-75
206	Mo./14	8229	8229	8292			(0) 137-147	(4) 203-245	(1) 293-344	(3) 218-245	28-70
212	Mo./14	8238	8238	8166	8292		(1) 146-178	(5) 217-248	(1) 293-332	(3) 227-248	24-64
217	Mo./14	8247	8247	8130	8302		(1-130) 138-148	(1-247) 203-244	(2) 298-353	(1-247) 218-244	26-67
233	Ohio/63	8248	8248	8302			(0) 145-161	(1) 208-245	(2) 285-334	(1) 222-245	31-66

TABLE C-2.- Continued.

Segment number	State/APU	Separation date	Acquisitions processed				Biowindow range (no. of acquisitions)				Scatter plot break
			Base date	2	3	4	A	B	C	Separation	
238	Ohio/28	8249	8249	8150			(1) 144-159	(2) 206-259	(0) 287-332	(2) 218-259	29-62
800	Iowa/25	8246	8218	8164	8246	8308	(1-164) 147-162	(3) 207-249	(1) 309-360	(1) 225-249	24-64
802	Iowa/25	8219	8219	8156	8318		(1) 147-160	(2) 207-254	(1) 305-340	(1) 228-254	30-73
806	Ill./25	8219	8219	8156	8308		(1) 141-161	(1) 201-252	(2) 290-326	(1) 217-252	29-71
809	Ill./25	8244	8218	8244	8307		(0) 140-157	(2) 206-248	(1) 293-331	(1) 222-248	20-54
820	Ill./25	8235	8235	8306			(1) 141-160	(4) 212-242	(1) 291-322	(3) 227-242	28-72
821	Ill./25	8235	8235	8163	8307		(2) 140-163	(4) 213-243	(1) 283-324	(3) 227-243	21-71
822	Ill./28	8234	8234	8306	8252		(0) 143-160	(3) 213-241	(1) 293-325	(1) 227-241	24-63
825	Ill./28	8234	8234	8153	8297		(1) 142-161	(2) 211-242	(3) 293-324	(2) 232-242	27-64
826	Ill./28	8234	8234	8117	8306		(1-117) 142-161	(3) 212-242	(1) 292-325	(2) 227-242	25-67
827	Ill./28	8243	8243	8306			(0) 142-161	(4) 213-243	(1) 292-324	(2) 227-243	23-63
828	Ill./28	8234	8234	8271	8163		(1) 142-166	(3) 213-236	(0) 293-349	(1) 227-236	29-65
830	Ill./28	8234	8234	8306			(0) 141-160	(3) 212-242	(1) 291-322	(2) 227-242	27-65
832	Ind./28	8232	8232	8313	8151		(2) 145-166	(1) 213-246	(2) 291-349	(1) 230-246	35-69
834	Ind./28	8251	8251	8305	8160		(3) 145-161	(3) 212-253	(2) 283-342	(3) 224-253	23-62

TABLE C-2.- Continued.

Segment number	State/APU	Separation date	Acquisitions processed				Biowindow range (no. of acquisitions)				Scatter plot break
			Base date	2	3	4	A	B	C	Separation	
835	Ind./28	8232	8232	8160	8304		(2) 145-161	(1) 211-243	(2) 283-343	(1) 225-243	30-63
836	Ind./28	8234	8234	8306			(0) 145-161	(4) 206-248	(3) 285-336	(2) 223-248	24-66
837	Ind./28	8234	8234	8306			(0) 145-161	(5) 205-245	(1) 290-334	(3) 224-245	21-66
839	Ind./28	8233	8233	8305	8160		(3) 147-161	(2) 209-248	(1) 291-344	(2) 224-248	36-67
840	Ind./28	8233	8233	8313	8160		(2) 145-162	(3) 210-250	(3) 292-345	(3) 227-250	25-64
842	Ind./28	8232	8232	8313	8160		(1) 145-162	(2) 210-252	(3) 293-	(2) 229-252	26-68
843	Ind./28	8232	8232	8313	8152		(3) 147-161	(2) 209-248	(2) 293-	(2) 232-248	32-69
847	Ind./28	8232	8232	8151	8313		(2) 138-163	(1) 211-249	(3) 293-349	(1) 227-249	35-67
848	Ind./28	8233	8233	8305	8160		(3) 145-161	(2) 207-243	(2) 283-339	(2) 222-243	30-73
849	Ind./28	8233	8233	8305	8151		(4) 146-162	(2) 209-243	(1) 282-334	(2) 220-243	28-66
851	Ind./28	8234	8234	8306	8198	8126	(0) 144-161	(4) 208-249	(1) 283-334	(3) 222-249	28-64
852	Ind./28	8232	8232	8313	8151		(2) 145-161	(2) 210-253	(3) 293-	(2) 225-253	29-74
853	Ind./28	8232	8232	8313	8151		(2) 145-162	(1) 208-245	(2) 293-	(1) 227-245	29-69
855	Ind./28	8233	8233	8305	8161		(2) 146-161	(4) 211-243	(1) 283-336	(3) 224-243	36-69

TABLE C-2.- Continued.

Segment number	State/APU	Separation date	Acquisitions processed				Biowindow range (no. of acquisitions)				Scatter plot break
			Base date	2	3	4	A	B	C	Separation	
856	Ind./28	8234	8234	8306	8161		(2) 148-161	(3) 210-242	(2) 284-334	(1) 223-242	28-65
860	Ind./28	8232	8232	8304	8152		(3) 145-161	(2) 214-247	(1) 288-340	(2) 232-247	36-68
862	Iowa/24	8231	8231	8303	8150		(1) 142-156	(2) 207-249	(1) 300-336	(1) 222-249	34-59
863	Iowa/24	8221	8221	8311	8150		(1) 144-162	(1) 207-252	(2) 300-354	(0) 225-252	32-68
864	Iowa/24	8231	8267	8150	8231		(2) 138-162	(2) 208-252	(1) 300-336	(0) 225-252	33-58
865	Iowa/14	8231	8231	8150	8267		(2) 144-162	(2) 207-252	(0) 300-336	(2) 225-252	29-54
866	Iowa/24	8221	8221	8311	8150		(1) 144-159	(3) 208-246	(2) 301-334	(3) 218-246	31-65
867	Iowa/24	8222	8222	8150	8303		(1) 144-156	(3) 208-244	(2) 303-333	(2) 216-244	26-63
868	Iowa/24	8221	8221	8166	8302		(0) 144-147	(2) 206-252	(2) 299-336	(2) 222-252	27-63
869	Iowa/24	8221	8221	8311			(0) 144-147	(1) 204-248	(1) 298-334	(1) 221-248	26-62
870	Iowa/24	8221	8221	8311			(0) 147-153	(1) 207-252	(1) 300-348	(1) 222-252	33-69
871	Iowa/24	8221	8221	8311			(0) 144-150	(1) 207-251	(1) 298-336	(0) 225-251	32-65
874	Iowa/24	8221	8221	8311			(0) 144-162	(1) 207-252	(1) 300-338	(1) 214-252	27-64

TABLE C-2.- Continued.

Segment number	State/APU	Separation date	Acquisitions processed				Biowindow range (no. of acquisitions)				Scatter plot break
			Base date	2	3	4	A	B	C	Separation	
875	Iowa/24	8221	8221	8293			(0) 142-160	(1) 207-251	(1-293) 300-337	(1-221) 225-251	30-66
876	Iowa/14	8231	8231	8141			(1) 141-159	(1) 207-252	(0) 300-336	(1) 233-252	32-63
877	Iowa/14	8231	8231	8141	8267		(1) 144-161	(2) 208-251	(0) 300-336	(0) 244-251	28-53
880	Iowa/14	8231	8231	8150	8267		(1) 144-162	(2) 207-250	(0) 300-339	(1) 225-250	30-56
881	Iowa/14	8231	8231	8267	8141		(2) 144-162	(3) 209-252	(0) 300-336	(1) 225-336	42-69
882	Iowa/24	8231	8231	8150	8303		(1) 144-159	(3) 213-248	(2) 300-342	(2) 218-248	35-63
884	Iowa/24	8231	8231	8311	8150		(1) 144-157	(3) 208-244	(3) 302-332	(2) 218-244	31-53
885	Iowa/24	8222	8222	8153	8303		(1) 144-162	(3) 206-245	(2) 300-333	(2) 219-245	29-66
887	Iowa/14	8222	8222	8159			(1) 142-146	(3) 203-242	(2) 301-335	(2) 212-242	31-69
888	Iowa/14	8231	8231	8294	8150		(2) 141-156	(2) 206-246	(1) 300-335	(1) 214-246	31-67
890	Iowa/24	8231	8231	8141	8303		(1) 141-159	(2) 207-252	(1) 300-336	(2) 221-252	31-61
894	Iowa/24	8221	8221	8311			(0) 143-148	(1) 206-249	(1) 300-335	(0) 223-249	32-65
895	Iowa/14	8231	8231	8159			(3) 141-159	(3) 207-250	(1) 300-335	(2) 222-250	32-64
896	Iowa/14	8231	8231	8150			(1) 143-159	(2) 208-250	(0) 303-335	(1) 224-250	33-67

TABLE C-2.- Concluded.

Segment number	State/APU	Separation date	Acquisitions processed				Biowindow range (no. of acquisitions)				Scatter plot break
			Base date	2	3	4	A	B	C	Separation	
897	Iowa/14	8222	8222	8141			(3) 141-161	(2) 207-250	(0) 300-336	(2) 222-250	28-68
898	Iowa/24	8221	8221	8311			(0) 142-147	(1) 208-248	(1) 300-335	(1) 223-248	26-66
899	Iowa/24	8221	8221	8311			(0) 141-156	(1) 207-249	(1) 299-336	(1) 221-249	27-63
1872	Minn./24	8222	8222	8150			(1) 141-150	(4) 204-250	(0) 294-321	(3) 213-250	32-65

NASA-JSC